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A Monthly Review of Surgical Science and Practice

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ANNALS *of* SURGERY

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BONE TUMORS. CENTRAL (MEDULLARY) GIANT-CELL TUMOR (SARCOMA) OF LOWER END OF ULNA, WITH EVIDENCE THAT COMPLETE DESTRUCTION OF THE BONY SHELL OR PERFORATION OF THE BONY SHELL IS NOT A SIGN OF INCREASED MALIGNANCY *

BY JOSEPH COLT BLOODGOOD, M.D.
OF BALTIMORE

A RECENT observation of this type of tumor involving the lower end of the ulna in which the bony shell was completely destroyed led to a reinvestigation of 47 cases of giant-cell tumor with especial reference to destruction of the bony shell or its perforation with infiltration of the surrounding soft parts.

This restudy has demonstrated that the complete destruction of the bony shell or its perforation at one or more spots with infiltration of the giant-cell tumor tissue has not been associated with any difference in malignancy.

The ultimate results in these 47 cases are almost all known at the present writing, and there have been no deaths from metastasis.

When the X-ray shows complete destruction of the bony shell, or when at operation the surgeon finds perforation of the capsule, the operator without this evidence will be inclined to do a more extensive operation—either an amputation or a more extensive resection which might interfere with the function of the limb.

The majority of these 47 cases of giant-cell tumor have come under the observation of a number of surgeons and pathologists, and from my correspondence with them, I am impelled to the conclusion that quite a number still consider this giant-cell tumor a *sarcoma,* and usually act on this conception and remove more than is necessary.

Distribution of the Central Giant-cell Tumor in the Forty-seven Cases Recorded in the Surgical Pathological Laboratory of the Johns Hopkins Hospital.—Radius, lower end, 13; tibia, 11; femur, 10; fibula and ulna, 3; astragalus and os calcis, 2; ilium, clavicle, phalanx of toe, each 1; humerus, none.

This does not include the giant-cell tumor of the upper and lower jaws.

* This article is a continuation of two others which have appeared in the ANNALS OF SURGERY, August, 1910, vol. lii, p. 145, and August, 1912, vol. lvi, p. 210.

This seems to suggest that the giant-cell tumor arises most frequently in the lower end of the femur, the upper end of the tibia, and the lower end of the radius—portions of bones of the skeleton subjected to the greatest trauma.

The first case to be reported in detail is of interest, because the local growth at the lower end of the ulna had the compressibility and softness of a cellular sarcoma. The X-ray showed complete destruction of the bony shell. The next point of interest which is rather unusual in the giant-cell tumor, was the fact that this tumor was so filled with spaces containing blood that it resembled a cavernous angioma.

Pathological Report (No. 23852).—*Giant-cell tumor of lower end of ulna. Operation: Resection with secondary bone transplantation.* (Figs. 1 to 19).

This patient (E. C.), a colored girl, aged twenty-six, was referred to me by Dr. Emory Marvel of Atlantic City.

The patient's attention was called to the ulnar portion of the right wrist by a painless swelling one year before operation. This swelling has increased rapidly in the past three months. There has never been pain and practically no loss of function.

Trauma.—The majority of the 47 cases give a history of trauma before the onset of any definite signs of a bone lesion, but in this case and in a few others the history of a trauma could not be obtained. The patient's occupation was that of a housemaid. During the past three months, when the swelling became distinctly more rapid, she found that washing and ironing produced fatigue, but until a few days before operation she continued to do without discomfort all other general housework.

The patient had consulted physicians and had received only X-ray treatment, until she came under the observation of Doctor Marvel, who immediately advised surgical intervention.

Fig. 1 shows the clinical appearance of the swelling. There was no œdema of the skin, except over the top of the tumor, and here an area of skin about the size of a silver dollar was œdematous and on palpation gave a suggestion that the tumor tissue had infiltrated at least into the subcutaneous fat. At the pathological examination this proved to be incorrect. The subcutaneous fat was not involved, and *the operator could have saved more skin.*

The tumor itself seems circumscribed, but it is compressible and soft and gives the sensation of fluctuation. The ulna above the tumor can be palpated and the tumor arises from the ulna abruptly. There was no pulsation.

The clinical appearance of the tumor was therefore more suggestive of a malignant cellular sarcoma.

Figs. 2 and 3 are the X-rays taken by Doctor Marvel about two weeks before Fig. 4, the X-ray taken by Doctor Kahn at St. Agnes Hospital. All show almost complete destruction of the bony shell. In Doctor Marvel's plates as well as in the plate made by Doctor

Kahn remains of the bony shell are present where the tumor expands abruptly from the shaft of the ulna, and here and there in all pictures remains of spicules of bone corresponding to the shell can be seen. In spite of this the shadow of the tumor is that of a circumscribed and not of an infiltrating local lesion. The radius and the carpal bones are not involved, nor does the ulna above the tumor nor any other bone show new periosteal bone formation.

From my experience with 13 cases of giant-cell tumor involving the lower end of the radius I knew from at least three cases that the bony shell could be completely destroyed without being associated with any increase in malignancy.

In this colored girl the blood was negative for Wassermann, the urine showed no Bence-Jones bodies, and the X-ray revealed no other bone lesion and no signs of metastasis to the lungs.

Diagnosis Based on History, Examination and X-ray.—From my experience with now more than 300 bone tumors I concluded that this tumor belonged to the giant-cell group. I had never observed a bone aneurism (malignant hemorrhagic bone cyst) in this situation.

In view of the fact that the extensor and flexor tendons, which in this case rested on the rapidly enlarging tumor, were not at all interfered with as to function, one could conclude almost positively that this tumor was still confined within a definite capsule, and that it could be resected without injury to the tendons. This proved to be correct.

Operation.—St. Agnes Hospital, January 4, 1919. The patient was anæsthetized with ether. No Esmarch was employed. Fig. 5 shows the beginning of the skin incision with the dissection of the flap and the removal of a fairly large area of œdematous and adherent skin.

Removal of the Skin.—Although I was quite confident that this was a giant-cell tumor, yet, when I came to operate, the fear of cutting into the tumor which is really not dangerous led me to remove more skin than was actually necessary. Fortunately sufficient was left to close the wound, but this removal of more skin than necessary complicated the secondary bone transplantation and has left a slight deformity in the sense of a narrow wrist. Had I cut into the skin I could have easily demonstrated that it and its subcutaneous fat were not infiltrated by the tumor. All of the flexor and extensor tendons could easily be separated from the capsule of the tumor, except the extensor carpi ulnaris and the extensor to the little finger. The former was divided on both sides of the tumor and no attempt was made to repair the defect. The remaining lower portion of the extensor to the little finger was sutured to the common extensor. (Function is now almost completely restored.) The ulnar vessels and the ulnar nerve were quite adherent to the capsule of the tumor. The vessels were ligated on both sides of the tumor. However, in dissecting the ulnar nerve from the capsule of the tumor, a little serum escaped. At this point the

capsule was thinnest. Immediately this portion of the tumor was covered with an alcohol sponge.

As the X-rays showed complete destruction of the lower end of the ulna, I felt that it was safer to remove the ulnar side of the lower end of the radius and to remove two carpal bones. This would not interfere with future function, and probably an attempt at disarticulation would have broken into the tumor at this point.

In removing the tumor the capsule was never injured and no fluid escaped, except when the ulnar nerve was dissected from the capsule.

Fig. 6 shows the method of preserving the ulnar nerve and the alcohol sponge over the slight perforation of the capsule.

Fig. 7 shows the method of removing the lower end of the radius and the carpal bones. Fig. 8 shows the stage of the operation when the tumor is held by an attachment to the lower portion of the extensor carpi ulnaris. Fig. 9 illustrates the closure of the wound without drainage. This also illustrates the narrowing of the wrist over the ulnar area due to the removal of too much skin. Fig. 10, an X-ray after operation, shows the ulnar defect.

This defect was repaired by the transplantation of a piece of the shaft of the tibia January 30, 1919, twenty-four days after resection.

Fig. 11 shows the transplant in place.

On February 20th, about three weeks after bone transplantation, all dressings were removed and the patient began to use the arm and hand with fair function.

Gross Pathology.—The ulna above the tumor, the distinct tumor capsule, the skin and subcutaneous fat removed with the tumor are shown in Fig. 12.

In the fresh, when I cut the tumor open it had a distinct capsule which varied in thickness from 1 to 5 mm. The cut surface of the tumor showed numerous cavities filled with blood not unlike a cavernous angioma. A few larger cavities contained clear serum unusual in angioma. Ramifying throughout the tumor were irregular areas of yellow, firm tissue not unlike fibrin, but there were no distinct firm whitish areas resembling the ostitis fibrosa in bone cysts which are now and then met with in the giant-cell tumor. Other portions of the tumor were red and spongy, more like a capillary angioma than the typical giant-cell tumor tissue. There was no infiltration of this vascular tissue beyond the capsule, but in the thicker portions of the capsule vascular areas could be made out between the fibrous strands of the capsule. The tumor was therefore present in the capsule, but had not perforated its outer layer. No bone could be seen or felt, except at one point when spicules were felt in cutting through the capsule near the ulna.

The surface of this tumor, after it had been in formalin a few days, is shown in Fig. 13, but it is not as characteristic as the surface appearance of the freshly cut tumor, nor the surface appearance (Fig. 14) of a photograph taken immediately after a fresh cut through the formalin specimen. In this picture (Fig. 14) we see the distinct capsule varying in thickness, the small and large blood cavities, the white irregular branching lines which in the fresh were yellow and suggested fibrin, and the spongy red areas. We can even make out in this picture the red areas in the thicker portions of the capsule.

The tumor, therefore, in its gross pathology differed from the ordinary giant-cell tumor chiefly in the presence of numerous small and large cavities filled with blood.

Microscopic Pathology.—Fig. 15 (low power) pictures the capsule with giant-cell and vascular areas present between the fibrous tissue, but at no point in the microscopic section study does tumor tissue perforate the capsule.

The presence of blood in small and large cavities and intimately mixed with the giant-cell tumor tissue is shown in Fig. 16. The blood cavities, however, are not vessels, as they are not lined by endothelium, but represent hemorrhage into tumor tissue. The tumor itself is filled with small vessels of the capillary type, but the hemorrhage could have been from a larger artery entering the bone from the shaft or end.

In the tumor itself we see three typical areas: First, areas containing numerous giant cells (Fig. 17), areas with no giant cells, but differing only from the other areas in the absence of giant cells. (Fig. 18.) These cellular areas without giant cells and those containing giant cells might at first sight be looked upon as a mixed-celled sarcoma. But the pictures show that between the cells there are many fibroblasts and much eosin-staining connective tissue, much more than in the usual round-and-spindle-cell sarcoma. Many of the cells have the morphology of the endothelial cells, and many of the cellular areas suggest strongly endothelium-lined tubes of the capillary type. Some of the giant cells may be due to accumulations of proliferating endothelial cells; others, especially the larger ones, may represent the osteoclasts usually present in bone destruction. Fig. 19 taken from a yellow area in the gross specimen resembles organized fibrin.

From this study it is my conclusion that this tumor, in spite of its numerous areas without giant cells, belongs to the type of neoplasms that have been called in the literature giant-cell sarcoma, and for which I have suggested the term giant-cell tumor, until more is known of its etiology.

The more I study this group of local growths, the more convinced do I become that it belongs to a special type of angioma or granulation-tissue tumor of which the xanthoma is a variety.

The typical giant-cell tumors are observed on the alveolar border of the jaw and are usually called epulis. The etiological factor in this group seems to be granulation tissue from an infection about a tooth or its root cavity. The majority of tumors about the tendon sheaths contain giant cells and the stroma is not unlike the central giant-cell tumor of bone. These tendon-sheath tumors seem to have a distinct relation to trauma. The same type of giant-cell tumor, except much more vascular, is now and then observed in bursæ and joints. In the so-called xanthoma characterized by the presence of foam cells, giant cells of the type seen in the central giant-cell tumor of bone are either absent or present in only small numbers. But in all of these tumors containing giant cells, vascularity is a characteristic feature. The epulis bleeds when injured. If one explores the central giant-cell tumor of bone without an Esmarch, the tumor bleeds profusely, and in some cases after curetting it has been difficult to check the hemorrhage. In all of these so-called giant-cell tumors death from metastasis in the cases which I have studied has been conspicuous by its absence, while in all forms of cellular sarcoma death from metastasis to the lungs is conspicuous by its frequency.

That many central giant-cell tumors have remained well after curet-

ting and even after a second and third curetting is strong evidence of benignity, or a very low grade of malignancy.

Pathological Report (No. 6893).—*Giant-cell Tumor of Lower End of Ulna. Gross Pathology: Blood cyst; bony shell preserved. Curetting in 1905. Well, 1919; fourteen years.*

This case was reported by the late Dr. G. G. Davis, of Philadelphia (Univ. Penna. Bulletin, November, 1905, vol. xviii, p. 249). It is of especial interest not only because the giant-cell tumor had the gross appearance of a hemorrhagic bone cyst, but also because the patient, a girl, was but two and one-half years of age. There was no history of trauma. Swelling of the wrist appeared two months after an attack of tonsillitis. There was slight pain. As the swelling increased the pain lessened. The X-ray shows an expansion of the lower end of the ulna with the definite preservation of a bony shell. It looks more like a cyst than a solid giant-cell tumor. (Fig. 20.)

Dr. Davis operated nine months after the onset of the swelling. He exposed and removed a thin shell of bone and found a cavity filled with 5 cc. or more of thin, dark-brown fluid. The cavity extended upwards, gradually diminishing in size, to the middle of the shaft of the ulna. The cavity, therefore, was somewhat larger than that pictured in the X-ray. The bony shell had no distinct lining membrane. The lower portion of the cavity was filled with tumor tissue resembling reddish granulation tissue, soft in consistency. This tissue was removed with the curette, and the cavity packed with gauze. The wound healed rapidly. The microscopic report was "round-cell sarcoma with numerous giant cells."

The father of this patient, Dr. Charles C. Rankin, of Philadelphia, sent me an X-ray taken five years after operation. This showed that the bone has been restored absolutely to normal. Dr. Davis sent me some of the tissue and my sections show a typical giant-cell tumor in which there has been considerable hemorrhage. Dr. Rankin informed me in February, 1919—fourteen years after operation—that there have been no signs of recurrence.

Hemorrhagic Bone Cysts.—In my list of 47 cases this is the only example of a giant-cell tumor appearing as a hemorrhagic cyst. In one case in which the tumor was in the lower end of the femur I found a small cystic cavity, about the size of a twenty-five cent piece. In a few cases, similar to the one first reported here, there has been hemorrhage in the tumor with the formation of small and large cavities filled with blood.

Bone Aneurism. Malignant Bone Cyst.—In 1910[1] in reporting my observations on benign bone cysts and giant-cell sarcoma, I referred to three personally studied cases of the so-called "bone aneurism." In this group of tumors the bony shell is usually preserved, although in some cases it may be partially destroyed: the bone shell shows abrupt expansion. The X-ray shows no new bone formation. On exploration, this bony shell is distended with bloody fluid, and lining the shell, there is usually a narrow zone of hemorrhagic granular tumor tissue which under the microscope is composed chiefly of spindle and round cells. In some cases, mixed with these cells of the malignant sarcoma, there may be giant cells.

[1] Annals of Surgery, August, 1910; *Transactions Amer. Surg. Assn.*, 1910.

In 1913 [2] I again reported on the subject of bone aneurisms, and added two new cases of my own observation. Gaylord in 1903 [3] was first to make a comprehensive report on bone aneurisms in American literature. Later Nakayama [4] reported three cases from Garré's clinic in Bonn and added some new cases from the literature. In 1910 Le Denuc,[5] reported seven new cases with a resumé of the entire literature.

It is important to note here that Davis's case, in the lower end of the ulna resembles in the *gross* the so-called bone aneurism, but his patient has remained well fourteen years after a simple curetting. The majority of the cases reported in the literature died of metastasis in spite of amputation, and microscopically the tumor tissue does not resemble a giant-cell tumor, but the most malignant spindle-and-round-cell sarcoma.

Malignant sarcoma of the round-and-spindle-cell type, or of the perithelial type are often observed in the soft parts as blood cysts or hematomas. All of the cases observed by me have died of metastasis. I have suggested that the bone aneurism be called a *malignant bone cyst* in order to contrast it with the *benign bone cyst* which in my experience has never contained blood.

I propose in a second article to consider more in detail this group of tumors, but Davis's observation demonstrates that the giant-cell tumor may appear as a hemorrhagic bone cyst resembling the malignant bone cyst.

In 1902 [6] I referred to the contributions of Kramer [7] and Jenckel [8] who report on the benignity of giant-cell sarcomas and that they can be cured by curetting. Kramer states that now and then the giant-cell tumor may appear as a "bone blood cyst," but that one can recognize the typical giant-cell tumor tissue attached to the bone shell. He does not report any such cases in detail. The case reported by Jenckel was a blood cyst containing spicules of bone in its capsule. The tumor was in the region of the neck of the femur and arose from the trochanter minor. It was therefore a periosteal and not a central tumor. This cyst was enucleated. Giant-cell tumor tissue was found in the wall of the cyst. The patient remained well thirteen years after operation.

Pathological Report (No. 12474).—*Solid Giant-cell Tumor. Lower End of the Ulna. Bony shell preserved. Resection with transplantation in 1912. Well with perfect function in 1919, seven years after operation* (Figs. 21 to 24).

This patient was referred to me by the late Dr. George Ben

[2] *Progressive Medicine*, December, 1913.
[3] ANNALS OF SURGERY, 1903, vol. xxxvii, page 834.
[4] *Beitr. z. klin. Chir.*, 1909, vol. lxiv, p. 524.
[5] *Centralbl. f. Chir.*, 1910, vol. xxxvii, p. 647.
[6] *Progressive Medicine*, December, 1902, p. 153.
[7] *Arch. f. klin. Chir.*, 1902, vol. lxvi, p. 792.
[8] *Deut. Zeitschr. f. Chir.*, 1902, vol. lxiv, p. 66.

Johnson of Richmond. He was a white male aged forty-eight; eight months before operation there was a sprain of the right wrist in cranking an automobile. This was followed by some discomfort for two months. Then there was a second injury with slight increase of discomfort. Six weeks before operation, a third sprain, one week after which he observed the swelling. In a few days an X-ray (Fig. 21) was made by Doctor Gray of Richmond. This shows the preservation of a thin bony shell. The peculiar marking of the tumor shadow into irregular lobules is in my experience rather characteristic of the central giant-cell tumor.

The X-ray shows that the styloid process is involved, but its contours are as yet not distorted.

In this case I decided that it was better, in view of the thin bony shell, to resect and transplant rather than curet. This operation could be done as quickly and *promised equally good function.* The resection was done February 23, 1912. The transplant was taken from the shaft of the ulna above and is shown in Fig. 23. The wound healed, the patient had only a short period of disability, there has been no loss of function, and the patient is able to crank and run his automobile (Fig. 23).

Gross Pathology.—The cut surface of the tumor (Fig. 24) shows a distinct bone capsule, and the cavity is filled with the typical granular reddish-brown giant-cell tumor tissue. We could also observe here and there small whitish areas firmer in consistency which resembled the ostitis fibrosa of the bone cyst. The sections from this tumor show typical giant-cell tissue and areas of ostitis fibrosa.

Summary.—These three cases situated in the lower end of the ulna are examples of the three types of the giant-cell tumor.

Pathological Report No. 12474 corresponds in its X-ray picture, in the preservation of the bony shell and in the presence of a solid tumor filling the bony shell, to the more common appearance of the giant-cell tumor, irrespective of its situation.

Pathological Report No. 23852 represents a less frequent type in which the tumor is filled with small and large cavities containing blood and resembling somewhat a cavernous angioma, and also one in which the bony shell has been destroyed.

Pathological Report No. 6893 is practically unique in my series in that the marrow tumor is chiefly a blood cyst.

In the fourth type of giant-cell tumor there is a perforation of the bony shell or fibrous capsule with infiltration of tumor tissue into the surrounding soft parts. This variety was not observed in the tumors involving the lower end of the ulna.

Hemorrhage Into the Giant-cell Tumor.—In my own cases and from the description of other surgeons the giant-cell tumor always looks vascular. On the whole, it resembles œdematous granulation tissue, but it is much more friable, because it has no intercellular fibrous-tissue stroma, nor elastic tissue. It is apparently composed of endothelium-lined vessels

FIG. 1.—Pathological Report No. 23852. Central giant-cell tumor of lower end of ulna. Colored female, aged twenty-six; swelling one year; clinically like a malignant sarcoma (malignant hemorrhagic bone cyst).

FIG. 2.—Pathological Report No. 23852. X-ray of giant-cell tumor of lower end of ulna showing almost complete destruction of bony shell. Anteroposterior view. This picture shows that there is no destruction of the radius or carpal bones. Compare with FIG. 4. (X-ray sent by Dr. Marvel.)

FIG. 3.—Pathological Report No. 23852. Lateral view (see Fig. 2). Compare with Fig. 4. X-ray sent by Dr. Marvel.

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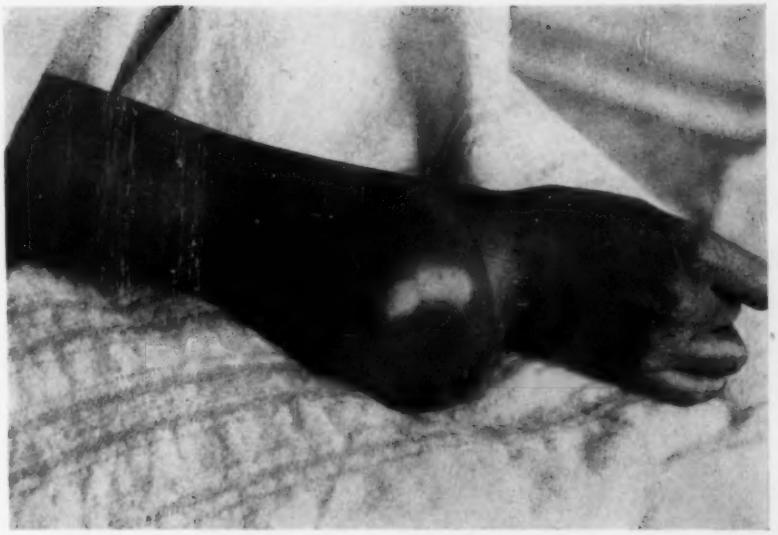

FIG. 1.—Pathological Report No. 23852. Central giant-cell tumor of lower end of ulna. Colored female, aged twenty-six; swelling one year; clinically like a malignant sarcoma (malignant hemorrhagic bone cyst).

FIG. 2.—Pathological Report No. 23852. X-ray of giant-cell tumor of lower end of ulna showing almost complete destruction of bony shell. Anteroposterior view. This picture shows that there is no destruction of the radius or carpal bones. Compare with Fig. 4. (X-ray sent by Dr. Marvel.)

FIG. 3.—Pathological Report No. 23852. Lateral view (see Fig. 2). Compare with Fig. 4. X-ray sent by Dr. Marvel.

FIG. 4.—Pathological Report No. 23852. X-ray taken by Dr. Kahn at St. Agnes Hospital. Central giant-cell tumor of lower end of ulna of patient shown in Fig. 1. Compare with Figs. 2 and 3. Note the almost complete destruction of the bony shell, but the tumor is still circumscribed.

FIG. 5.—Pathological Report No. 23852. First step in operation on tumor shown in Fig. 1. The skin incision, exposure of ulna bone marking out of skin area to be removed.

FIG. 6.—Pathological Report No. 23852. Second stage of operation on tumor shown in Fig. 1. The ulnar nerve is being retracted in its dissection from the tumor. The sponge, wet in alcohol, is covering a small opening in the capsule of the tumor from which clear serum had escaped.

FIG. 7.—Pathological Report No. 23852. Third stage in the operation on tumor shown in Fig. 1. The bone forceps is biting off the ulnar side of the lower end of the radius. The tumor is now almost isolated.

FIG. 8.—Pathological Report No. 23852. The last stage in the operation for the removal of the tumor shown in Fig. 1. The tumor is still attached to the lower portion of the extensor capi ulnaris. The uninvolved tendons and muscles and carpal bones are pictured and the ulnar nerve is retracted by a loop of fine black silk.

FIG. 9.—Pathological Report No. 23852. The closure of the wound after the local excision of the tumor shown in Fig. 1. Had less skin been removed with the tumor the narrowing of the forearm at the wrist would have been less marked.

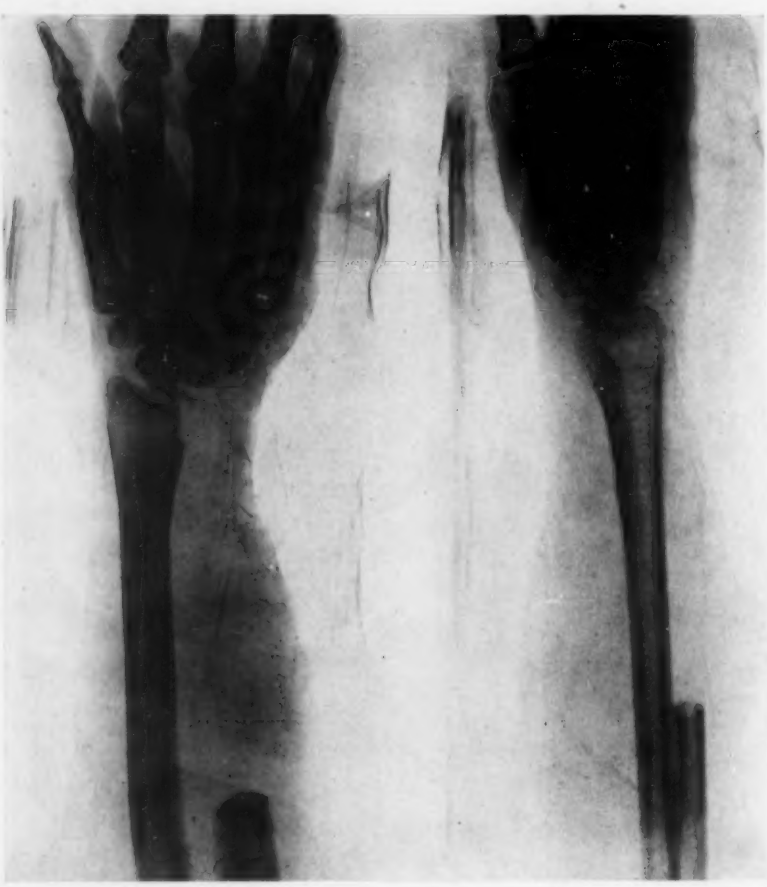

FIG. 10.—Pathological Report No. 23852. Anteroposterior and lateral X-rays by Dr. Kahn after the resection of the lower end of the ulna with the tumor shown in Fig. 1. This shows the piece of radius removed and the defect due to the removal of two carpal bones; also the narrowing of the forearm at the wrist due to excising of more skin than necessary.

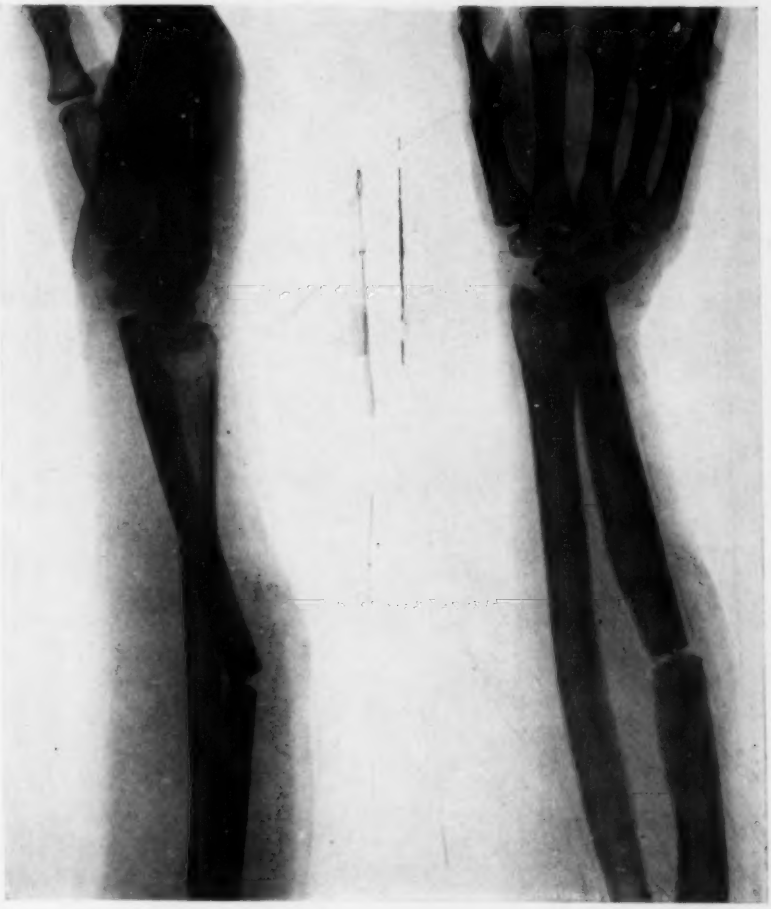

FIG. 11.—Pathological Report No. 23852. X-rays (anteroposterior and lateral) about ten days after bone transplantation from the tibia into the defect shown in Fig. 10. The pin of the transplant is seen in the marrow cavity of the upper end of the ulna. In the lateral view it appears as if this pin had fractured. Clinically there is no evidence of fracture at this junction.

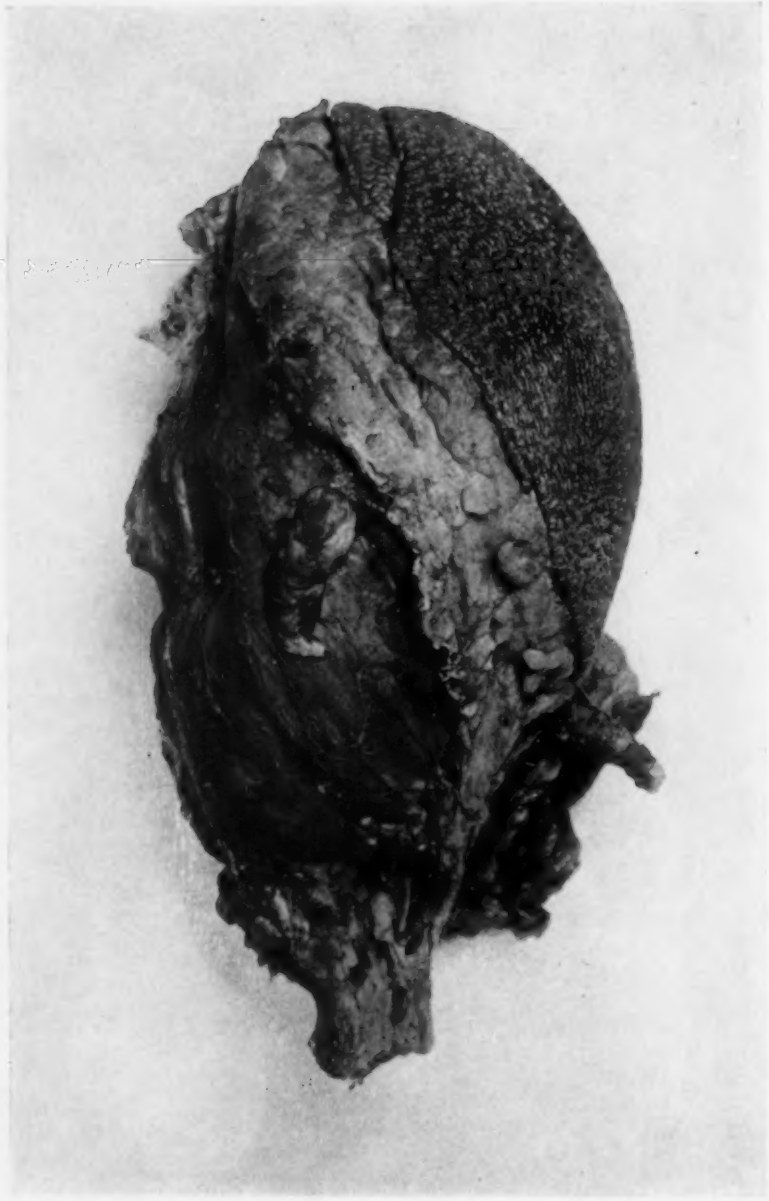

FIG. 12.—Pathological Report No. 23852. The removed skin, subcutaneous fat, capsule of tumor and piece of ulna of the tumor shown in Fig. 1. The examination of this specimen demonstrates that more skin could have been saved. The divided extensor tendon to the little finger is shown.

FIG. 13.—Pathological Report No. 23852. Surface appearance of a longitudinal section through the specimen of tumor shown in Fig. 1 after it had been in formalin a few days. The cavities which were filled with blood are pictured. The capsule is distinctly shown. Compare with Fig. 14.

FIG. 14.—Pathological Report No. 23852. Photograph of fresh cut through the formalin specimen. The spongy angiomatous character is shown in the many small and large cavities throughout the tumor. The irregular white septa are due to organized fibrin. The infiltration of the capsule is pictured. Compare with Fig. 13.

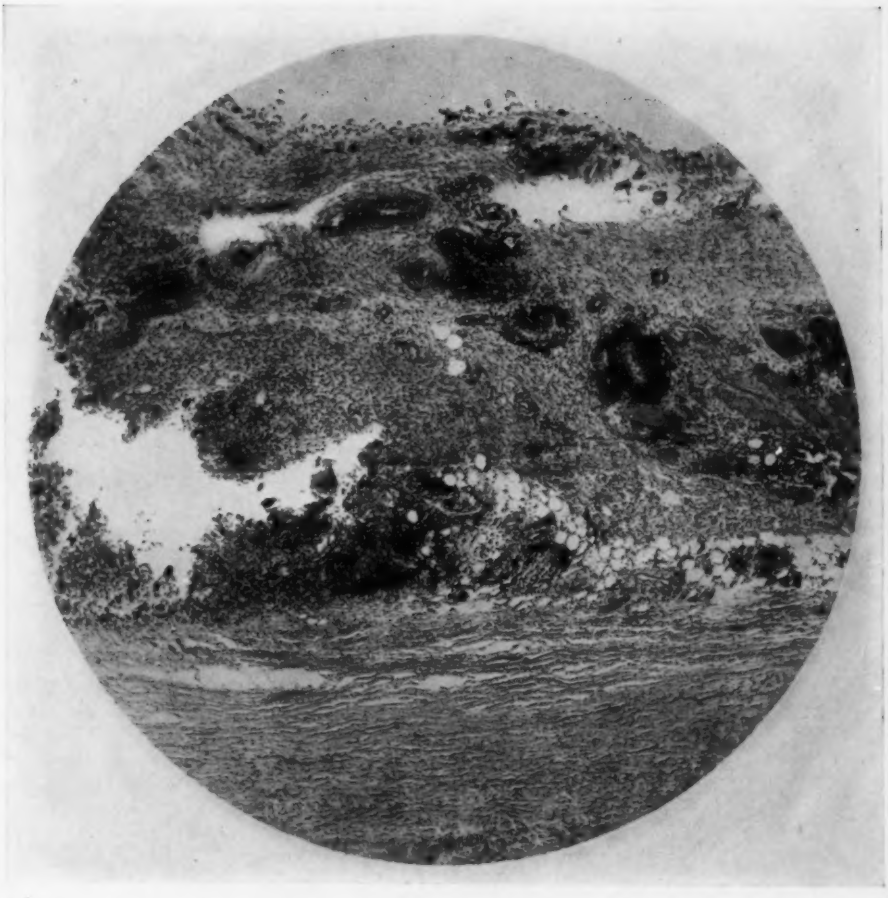

FIG. 15.—Pathological Report No. 23852. Photomicrograph (low power) of capsule of giant-cell tumor of lower end of ulna showing infiltration of capsule with vascular giant-cell tissue.

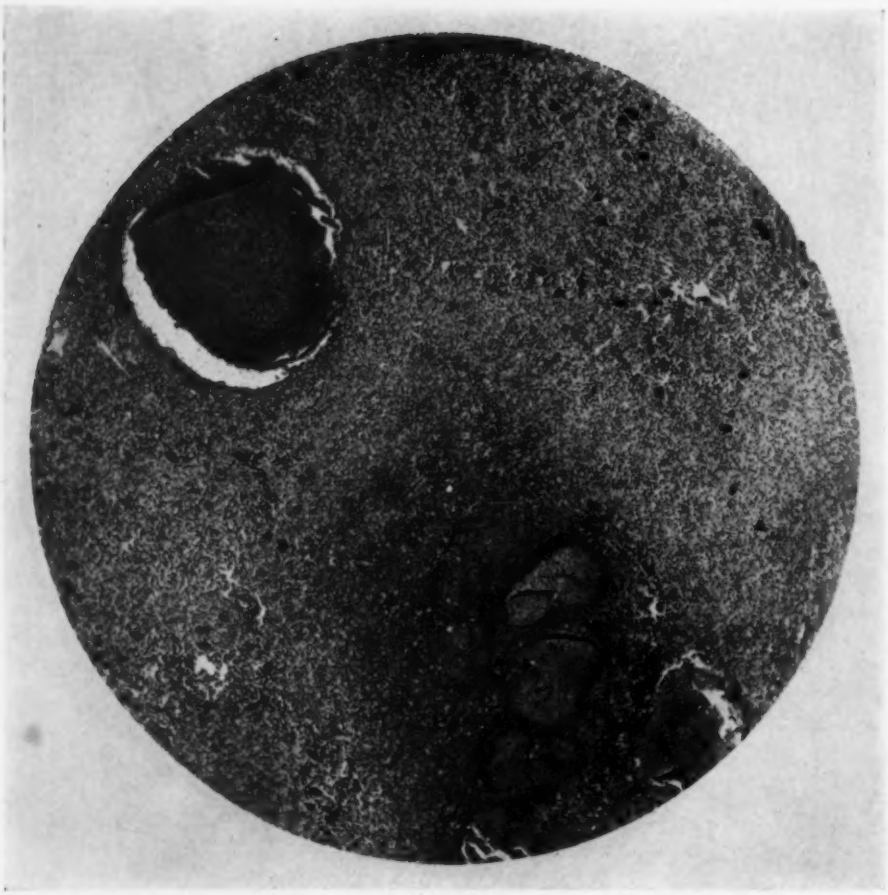

FIG. 16.—Pathological Report No. 23852. Photomicrograph (low power) illustrating the giant-cell tumor infiltrated with blood and blood cavities.

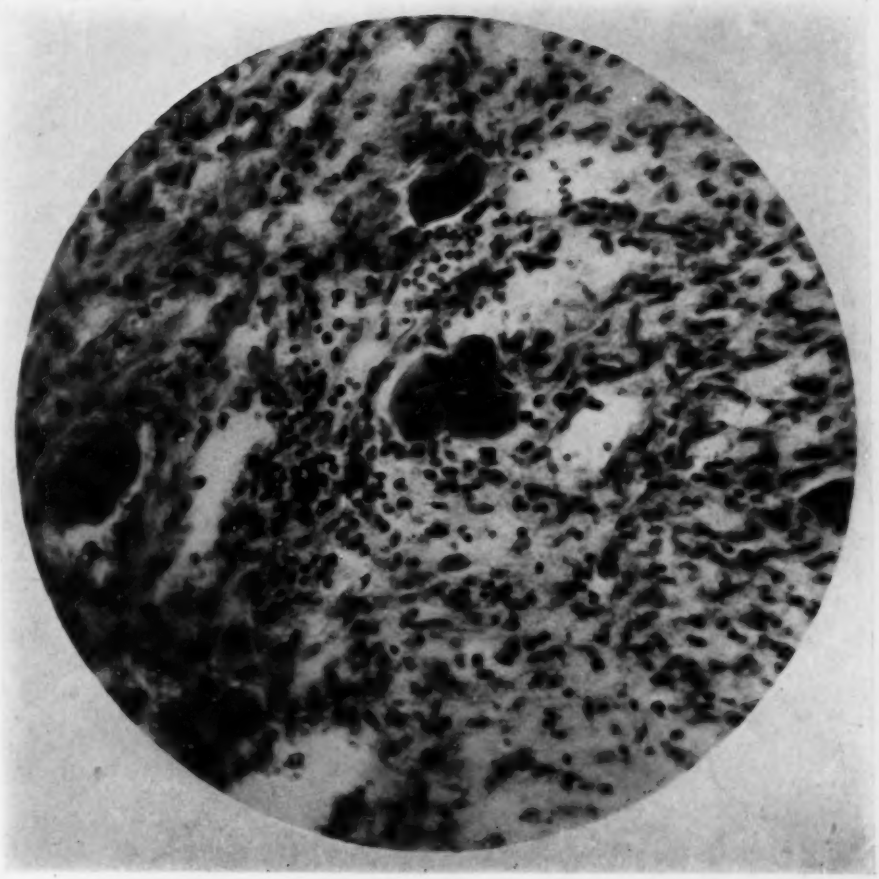

FIG. 17.—Pathological Report No. 23852. Photomicrograph (high dry power) showing the giant-cells imbedded in the vascular, cellular tumor tissue. This tumor tissue should easily be distinguished from a spindle-and-round-cell sarcoma. It resembles granulation tissue, or a very cellular capillary angioma.

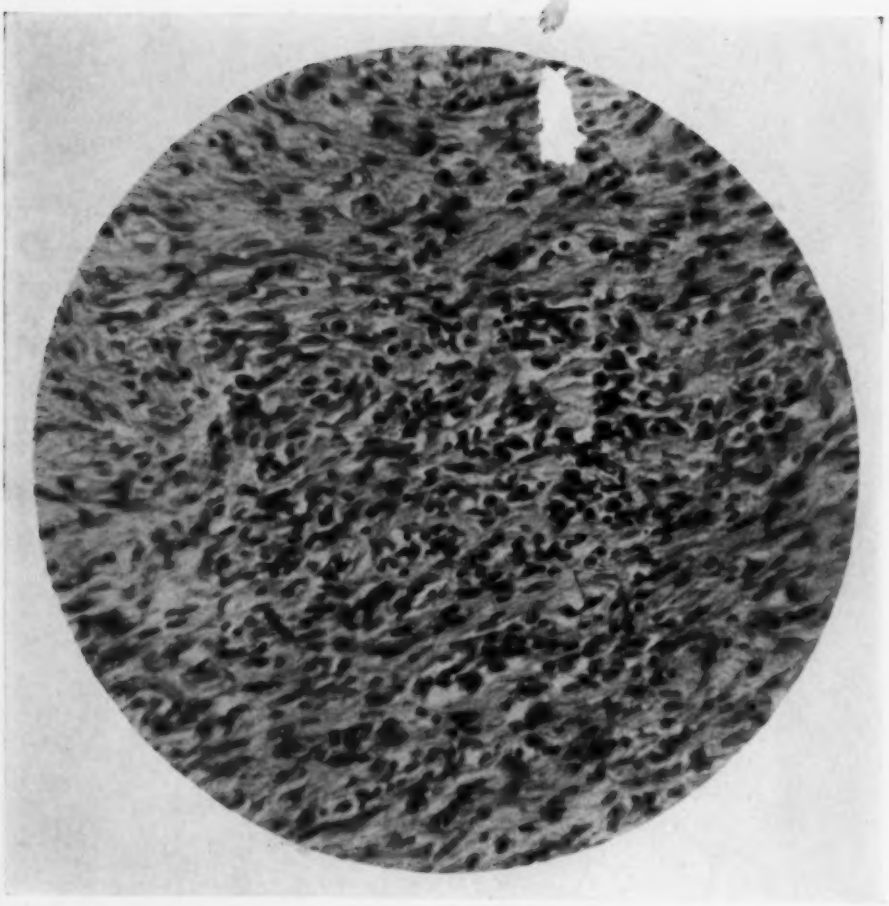

FIG. 18.—Pathological Report No. 23852. Photomicrograph (high dry power) of cellular tumor tissue in which there are no giant cells. Compare with Fig. 17.

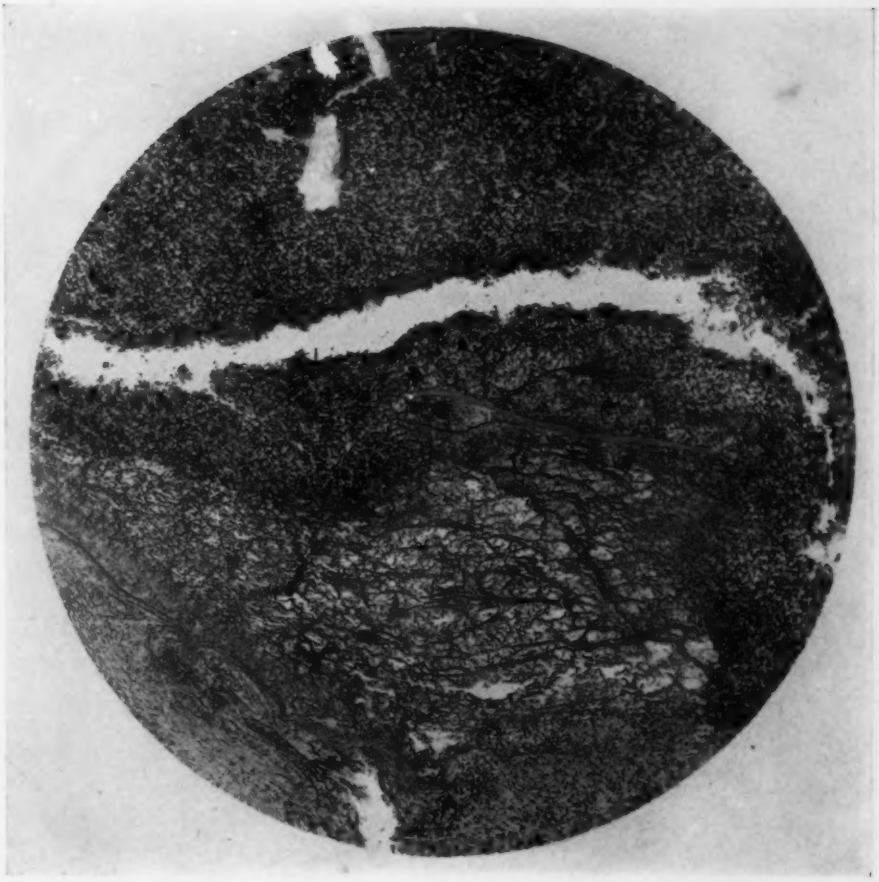

FIG. 19.—Pathological Report No. 23852. Photomicrograph (lower power) of an area of organized fibrin below from the white areas shown in Fig. 14 and the giant-cell tumor tissue above.

FIG. 20.—Pathological Report No. 6893. Giant-cell tumor of lower end of ulna. Davis's case. Previously reported in ANNALS OF SURGERY, August, 1910, vol. lii, Fig. 29.

FIG. 21.—Pathological Report No. 12474. X-ray of central giant-cell tumor of lower end of ulna. White male, aged 48; trauma eight months; pain, swelling two weeks. The bone capsule is distinctly preserved; the markings are those usually seen in the giant-cell tumor. This case has been reported in ANNALS OF SURGERY, Aug., 1912, vol. lvi.

FIG. 22.—Pathological Report No. 12474. X-ray after transplantation of piece of ulna in case shown in Fig. 21. (Previously reported in ANNALS OF SURGERY, August, 1912, vol. lvi, Fig. 29).

FIG. 23.—Pathological Report No. 12474. X-ray two years after operation on case shown in Figs. 21 and 22. The transplant has united by perfect bony union with the ulna. There is no restriction of function of the wrist, and weakness of the arm. (Not previously reported.)

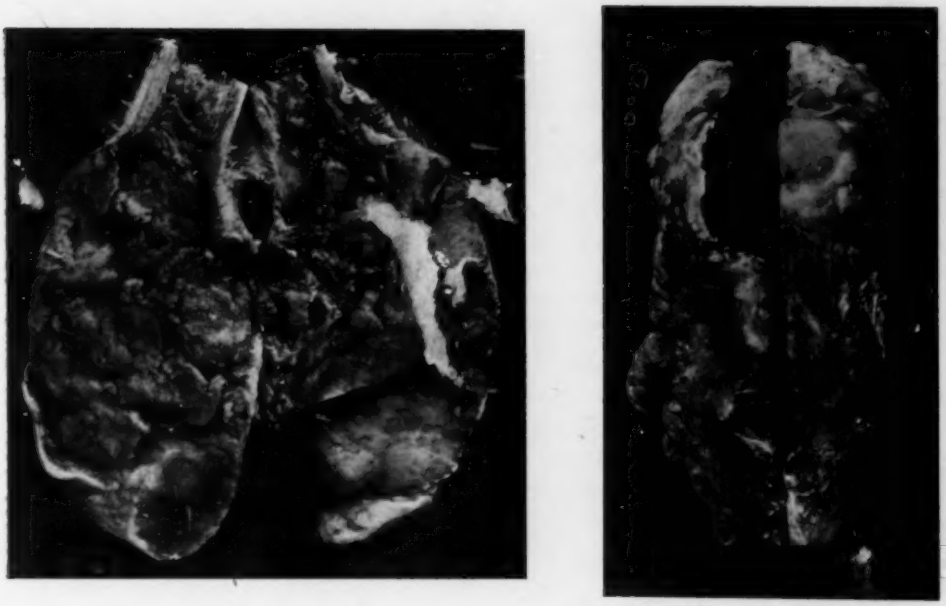

FIG. 24.—Pathological Report No. 12474. Photograph of bisected tumor after resection. See Fig. 21 for X-ray. This is the usual gross appearance of the giant-cell tumor. Compare with Figs. 13 and 14 which illustrate unusual appearance of the giant-cell tumor. (Previously reported in ANNALS OF SURGERY, August, 1912, vol. lvi, Fig. 28.)

FIG. 25.—Pathological Report No. 8680. Photograph of resected gross specimen of giant-cell tumor of lower end of radius, to show the absence of a bony shell and the gross appearance of a giant-cell tumor with red areas and areas of ostitis fibrosa. (Previously reported in ANNALS OF SURGERY, August, 1910, lii, Fig. 37.) Compare this with Figs. 13, 14 and 24.

containing blood surrounded by loose young cellular connective tissue, and throughout this tissue there are numerous giant cells. The color of the giant-cell tumor must be due to its vascularity, yet pulsation has been observed in but two cases. When the tumors have been curetted from the bony shell, all operators have noted the great hemorrhage from vessels perforating the bony shell. When I curetted a giant-cell tumor of the upper end of the tibia in December, 1902,[9] and removed the Esmarch the bleeding was so profuse that we had to replace the Esmarch and pack the bone cavity with gauze, using a chisel and a hammer. This patient is well in 1919, seventeen years since operation.

Dr. Frank Hinds,[10] of England, who was first to curet a very large giant-cell tumor in the lower end of the femur, reports a similar experience. He also had to use a tourniquet and to pack. Doctor Taylor, of Philadelphia, had an experience similar to Hinds's.

In view of this great vascularity it would not seem unexpected to observe even more frequently evidences of hemorrhage into the giant-cell tumor tissue similar to the first case reported in this article, or even sufficient to produce a blood cyst resembling Davis's case. But on the whole this extreme hemorrhage has not been observed except in a few cases. With the exception of Davis's case marked hemorrhage into the tumor tissue as pictured in the first case reported here, has only been noted when the bony shell had been completely or partially destroyed. The destruction of the bony shell would undoubtedly allow the vascular tumor tissue to be subjected to trauma more readily and this explains the hemorrhage.

Evidence that Perforation or Destruction of the Bony Shell by the Giant-cell Tumor does not Indicate Increased Malignancy of the Tumor.—My conception of malignancy in sarcoma is metastasis to the internal organs or neighboring lymphatics. In the Surgical Pathological Laboratory of the Johns Hopkins Hospital we have recorded a large number of periosteal and central sarcomas of bone and sarcoma of the soft parts and glands. The vast majority of these patients have died of metastasis to the lungs without local recurrence. The usual type of the tumor is spindle-and-round-cell sarcoma, sometimes with a perithelial arrangement. In these 47 cases of giant-cell tumor there is not a single example of death from any cause which could be attributed to the tumor. In many instances the local growth of the sarcoma which has caused death by metastasis, had been just as circumscribed and, in some instances, more circumscribed, than the local growth of the giant-cell tumor. The size of the local growth which produced death by metastasis is not necessarily large.

[9] *Johns Hopkins Hosp. Bull.*, May, 1903, vol. xiv, p. 133; *Progressive Medicine*, December, 1903, page 201.

[10] *British Med. Jour.*, February 26, 1898; *Progressive Medicine*, December, 1899, page 242.

It is therefore of the utmost importance, especially in relation to bone tumors, to be able to recognize the giant-cell tumor, because when it is recognized a cure should be accomplished with little or no mutilation *beyond that due to the destruction by the tumor itself.*

Giant-cell Tumor of the Lower End of the Radius. Thirteen Cases.—The bony shell had been more or less completely destroyed in four cases, perforated in two cases; it was completely intact in six cases, and in one case the tumor had recurred after resection of the lower end of the radius, and the condition of the shell in the original tumor could not be ascertained.

Pathological Report (No. 738).—Observed in the Johns Hopkins Surgical Clinic in 1894. The bony shell was completely destroyed; tumor tissue had broken through the capsule into the area of the carpal bone; the tumor was filled with blood; it pulsated. This patient is well 1919, twenty-five years after amputation.

Pathological Report (No. 2420).—I operated on this case in Johns Hopkins Hospital in 1901. On making an exploratory incision there was no bony shell; the tumor was very cellular and very hemorrhagic. It was my opinion then that it was a very malignant round-cell sarcoma of the perithelial type. The arm was amputated above the elbow. The gross specimen shows complete destruction of the bony shell, perforation of the capsule, infiltration of tumor tissue along the tendon sheath to the thumb. This patient was well in 1915—fourteen years since operation.

Pathological Report (No. 8680).—(Fig. 25.) Observed in the Johns Hopkins Surgical Clinic in 1908. The operation consisted of resection of radius, ulna and carpal bones. The gross specimen shows that the tumor is confined within a definite fibrous capsule, and the ulna and carpal bones are not involved. There was no perforation of the fibrous capsule. The tumor was composed of typical giant-cell tissue with areas of ostitis fibrosa. Resection of the lower end of the radius would have been sufficient. This patient is well 1919—eleven years since operation, and has very good function of the hand. She is able to do all her housework.

Pathological Report (No. 14044).—Observed in 1909 by Dr. Emil G. Beck, of Chicago. The bony shell was almost completely destroyed and the metacarpal bones were involved. Dr. Beck first curetted thoroughly. One year later because of recurrence he amputated the arm. This patient was well in 1915—six years since operation.

Pathological Report (No. 6125).[11]—In this case the bony shell was preserved, except at one point towards the radius where there was a slight perforation. The operation in 1905 at the Johns Hopkins Surgical Clinic consisted of resection of the lower ends of both bones. This patient was well in 1915—ten years since operation. From a study of the X-ray plate and the specimen, I am inclined to think curetting should have been tried first. The giant-cell tumor in the lower end of the radius with the exception of this perforation at one point is no more extensive than in Pathological Report No. 10376, curetted by Dr. Chambers, of Baltimore, in 1908 and well in 1919—eleven years since operation.

Pathological Report (No. 16720).—Operation by Dr. Harry M. Sherman, of San Francisco, in 1914. Dr. Sherman resected the lower end of the radius and some of the carpal bones, because the tumor had perforated the capsule and involved the carpal bones. This, however, does not show in the X-ray print sent to me. The patient is well in 1919—five years since operation.

Giant-cell Tumor of the Lower End of the Femur. Ten Cases.—In none of these cases was the bony shell completely destroyed, but in four cases there was perforation of the bony shell, with involvement of the soft parts in the popiteal space.

[11] Annals of Surgery, August, 1912, vol. lvi, Fig. 16.

Pathological Report (No. 2458).—Observed in the Johns Hopkins Surgical Clinic in 1899. The growth was first resected and then seven days later the limb was amputated through the thigh. Nine years later this patient's abdomen was explored in the Johns Hopkins Clinic and an inoperable cancer of the stomach found, which apparently had no relation to the previous bone tumor.

Pathological Report (No. 3623).—Observed in the Johns Hopkins Surgical Clinic in 1900. As the symptoms were those of gonorrhœal arthritis, there was a number of exploratory arthrotomies. The leg was amputated five months later. This patient died ten years later of tuberculosis of the lungs.

Pathological Report (No. 4396).—The thigh was amputated in the Johns Hopkins Clinic in 1903. The patient is well in 1919—fifteen years since operation.

Pathological Report (No. 13214).—Operated on in the Johns Hopkins Clinic in September, 1912. Resection of the lower end of the femur. Bone transplanted from the tibia. This patient is well in 1919, almost seven years since operation.

When we compare the ultimate results in these four cases of giant-cell tumor of the lower end of the femur which had perforated into the soft parts of the popliteal space with the spindle-and-round-cell sarcoma of the lower end of the femur with similar involvement of the soft parts, we find in the latter group every patient dead of metastasis within three years in spite of high amputation.

Giant-cell Tumor of the Tibia. Eleven Cases.—In only one case was the bony shell partially destroyed, and in one instance there was a small perforation of the bony shell.

Pathological Report (No. 10975).[13]—The tumor involved the upper end of the tibia. The X-ray resembled very closely the first case reported here. There was practically no bony shell. I resected this in 1910, and did a secondary bone transplantation. The patient is well in 1919—eight and one-half years since operation.

Pathological Report (No. 12207).[13]—The tumor involved the upper third of the shaft of the tibia. Dr. A. R. Kimpton, of Boston, operated in November, 1911, and noted that the periosteum and bony shell were perforated at one point. The operation consisted of curetting. This patient was well in 1915—four years since operation.

I have given this evidence in detail to emphasize the statement that destruction of the bony shell, partial or complete, or perforation and infiltration of the soft parts by the giant-cell tumor is not associated with metastasis and does not indicate a more radical procedure, beyond the removal of the tumor.

Evidence that Exploratory Incision and Recurrence do not Increase the Malignancy of the Local Growth of the Giant-cell Tumor.—This fact is of the greatest importance in justifying a less radical procedure, running the risk of a recurrence, if a more radical operation would mean amputation, or a resection with limited function.

Pathological Report (No. 8412).[14]—This patient came under my observation in 1907 with a recurrent tumor in the position of the lower end of the radius. The onset

[13] ANNALS OF SURGERY, August, 1912, vol. lvi, Figs. 17 to 23.

[13] ANNALS OF SURGERY, August, 1912, vol. lvi, Figs. 11 and 12.

[14] ANNALS OF SURGERY, August, 1912, vol. lvi, Fig. 14.

of the tumor had been twenty months before my operation. There had been three previous operations—two incomplete curettings and one resection of the lower end of the radius. The recurrent tumor was distinctly encapsulated, situated in the soft parts between the resected ends of the radius and the carpus. It was a typical giant-cell tumor. I was rather of the opinion that the recurrence was due to tumor transplant at one of the previous operations. I removed the tumor without injury to any of the tendons and transplanted a piece of ulna into the defect. This patient died seven and one-half years later from a cardiac lesion present at the time of my operation.

Pathological Report (No. 1815).[35]—In this case the tumor was in the lower end of the radius. There had been an exploratory incision fourteen months before the operation at the Johns Hopkins Clinic in May, 1897. I assisted Doctor Halsted at this operation. The tumor was explored. In spite of the previous operation the bony shell had healed completely and there was no tumor tissue outside the bony shell. The explored tumor was vascular and pigmented. At that time (1897) our diagnosis was a cellular sarcoma of malignant type. The arm was amputated, and the enlarged epitrochlear and axillary glands were removed. The tumor proved to be a giant-cell growth. The enlarged glands contained blood pigment, but no tumor cells. This patient is well in 1919—twenty-two years after operation. This case has been reported in the ANNALS OF SURGERY for August, 1912, vol. lvi, p. 210.

Pathological Report (No. 14044).—This case has been mentioned before as the bony shell was destroyed and the carpus infiltrated. Dr. Emil G. Beck, of Chicago, curetted the giant-cell tumor in the lower end of the radius in 1909 and amputated for a recurrence in 1910. The patient was well in 1915.

Pathological Report (No. 7440).[36]—Dr. William J. Taylor, of Philadelphia, curetted a giant-cell tumor in the lower end of the femur in 1906; encountered extreme hemorrhage and was compelled to pack the cavity; curetting was probably incomplete. The leg was amputated about one year later for a recurrence. This patient was well in 1918—eleven years since operation.

Pathological Report (No. 7851).[37]—Giant-cell tumor of the lower end of femur. The late Dr. John B. Murphy, of Chicago, explored and removed a piece for diagnosis. Some weeks later Dr. James F. Mitchell, of Washington, amputated the thigh. This patient was well in 1914—seven years since operation.

Pathological Report (No. 12926).[38]—Giant-cell tumor in upper end of fibula. This was curetted in 1911 by Dr. John W. Chambers, of Baltimore. It was resected for recurrence in 1915. The patient is well in 1919.

Recurrence After Operation for Benign Connective-tissue Tumors.—For years I have been interested in this observation, especially in the mixed tumors of the parotid, the intracanalicular myxoma of the breast, the myxoma of bone, the giant-cell epulis of the alveolar border of the jaws, the fibromyxoma of nerve-sheaths, and now and then in lipomas.

When recurrence has taken place in these groups of benign connective-tissue tumors, the operation had consisted in a rough enucleation. I have demonstrated in such tumors that the capsule is thin, and if torn pulls away with small particles of tumor tissue. At an operation of enucleation, therefore, if the capsule is torn, particles of tumor tissue could

[35] ANNALS OF SURGERY, August, 1912, vol. lvi, Fig. 34.
[36] ANNALS OF SURGERY, August, 1910, vol. lii, Fig. 31.
[37] ANNALS OF SURGERY, August, 1910, vol. lii, Fig. 38.
[38] ANNALS OF SURGERY, August, 1912, vol. lvi, Figs. 7, 8 and 9.

be left in the wound and their later growth would produce a recurrence. There is no question as to the fact of recurrence.

I have reoperated upon at least seven of such recurrent tumors in the region of the parotid, and when I could not excise because of injury to the facial nerve, I have enucleated, disinfecting the wound with pure carbolic and alcohol. There have been no recurrences. In the intracanalicular myxoma of the breast one can always excise and there has never been recurrence after these secondary complete excisions. In the older text books on surgery written by surgeons well trained in the pathology of tumors we frequently find the statement that the "pure myxoma of bone is a benign tumor, but that it usually recurs."

My records confirm this statement, but unfortunately in myxoma of bone the recurrent tumor often shows sarcomatous degeneration. This is also true of the fibromyxoma of nerve sheaths. Such tumors, therefore, should never be enucleated and not explored. If either is necessary, in order to establish the diagnosis or restrict mutilation, the wound should be swabbed with pure carbolic acid followed by alcohol, or the cautery should be employed. Personally, I have never had a recurrence when this technic has been followed. The object of this method is to destroy particles of tumor tissue that might be left in the wound when the tumor is explored or enucleated. The danger is greater in enucleation, but in myxoma of bone simple exploration seems to be sufficient.

When the giant-cell tumor of the alveolar border of the upper jaw is removed with the knife, recurrences are frequent; when removed with the cautery, there have not been any recurrences, and the operation has been less extensive.

The recurrences in lipoma have apparently been due to rough enucleation. I have one example in which the lipoma recurred three times in its situation in the thigh near the femoral vessels. These recurrences took place within three years. It is now more than four years since the operation performed by me in which the tumor was given a wide berth, except where it was adherent to the femoral vessels; at this point an alcohol sponge was employed, and the sheath of the vessel was removed. There has been no recurrence.

In fibromyxoma of nerve sheaths no attempt should be made to save the nerve trunk, if the tumor surrounds it. The nerve should be resected, because, although the original tumor may be benign, the recurrent tumor may be sarcoma and associated with metastasis.

I take space for this evidence here, because in my opinion some of the recurrences after curetting for giant-cell tumor may be explained by the neglect of cleansing the bony shell with some agent which will destroy remains of tumor tissue. I have always employed pure carbolic acid followed by alcohol. Hinds, after curetting a tumor in the lower end of the femur, packed the cavity with gauze saturated with chloride of zinc. As far as I can ascertain, all the successful cases of curetting for central

giant-cell tumor have had, in addition to a thorough curetting, some such method of chemical cauterization. One could employ the cautery.

Curetting for Giant-cell Tumor.—In 1899, nineteen years ago,[19] I reviewed the literature on the conservative treatment of sarcoma of the long pipe bones, and in that contribution I referred to the observation of Frank Hinds.[20] The giant-cell tumor filled the lower end of the femur and its condyles. The preoperative diagnosis was osteomyelitis. When Hinds explored and removed the expanded thin bony shell he exposed tumor tissue "dark-red in color," which could be easily scraped out with a sharp spoon. The bleeding was so profuse that an Esmarch had to be placed on the thigh. Hinds notes that the tumor involved both condyles and extended up the shaft for a depth of four inches. After curetting thoroughly the surface of the remaining bony shell was "scrubbed" with a solution of chloride of zinc and packed with gauze. Six weeks later the granulation tissue lining the bony shell looked suspicious, so that curetting and scrubbing with chloride of zinc was repeated. The microscopic sections of the curetted tumor showed "myeloid sarcoma with numerous giant cells." There was no microscopic study of the tissue removed at the second operation.

Doctor Hinds sent me sections of this tumor in 1914 (Pathological Report No. 13025). They show a typical giant-cell tumor. In 1916 Doctor Hinds wrote me from the war zone in France and enclosed a letter from this patient twenty-one years after operation. The patient has perfect function and works as a forester cutting down trees; carrying heavy weights and walking from ten to twelve miles a day. An X-ray print[21] was also sent me, demonstrating that the cavity is filled with bone.

This case of Hinds's represents the most extensive central giant-cell tumor treated by curetting, and the result in this case should encourage surgeons to use this method more frequently.

Among the ten examples of giant-cell tumor in the lower end of the femur in my list, curetting in at least eight cases offered as much chance of a permanent cure as in Hind's case. Yet, it was tried only in one other case, by Doctor Taylor,[22] of Philadelphia. The failure in Doctor Taylor's case, I think, was due to incomplete curetting because of the hemorrhage. I have the specimen removed at the later amputation, and I am of the opinion that it would have been justifiable to attempt a curetting a second time, using the Esmarch and some form of cauterization of the bony shell.

I have furnished the evidence that there is no risk in recurrence. In tumors of the lower end of the femur resection and bone transplantation rarely give as good function as amputation and an artificial limb. Curet-

[19] *Progressive Medicine*, December, 1899.
[20] Ibid., p. 242; *British Med. Jour.*, February 26, 1898.
[21] Annals of Surgery, August, 1912, Fig. 33.
[22] Annals of Surgery, August 1910, vol. lii, Fig. 31.

ting, therefore, offers the only method of a cure with perfect restoration of function.

In December, 1902, I had my first opportunity to try curetting. The giant-cell tumor involved the upper end of the tibia. This case has been reported.[23] The tumor was not as extensive as that operated on by Hinds. The patient was well in 1915—thirteen years later.

In the ANNALS OF SURGERY for August, 1910 (vol. lii), I reported on the cases which have been cured by curetting: Hinds's case in the lower end of the femur and my case in the upper end of the tibia just mentioned, Davis's case in the lower end of the ulna, again reported in this paper, and one in the lower end of the radius, curetted by Doctor Chambers. In ANNALS OF SURGERY for August, 1912, I made a further report mentioning cases from the literature. As far as I know there has been no recurrence in any of these cases. I have not gone over the literature since 1912.

Doctor Howard L. Prince, of Rochester, N. Y., wrote me in November, 1918, that he had curetted the following cases with good results: Upper end of the tibia, well five years; os calcis, two cases, well three and four years respectively after operation; upper end of ulna, one case, well six years after operation. Doctor Prince after curetting cauterizes the bone cavity with carbolic acid followed by alcohol.

I have seen the X-rays and tissue in most of these cases operated on by Doctor Prince.

CONCLUSIONS

I am confident that surgeons and pathologists should and can learn to recognize the central giant-cell tumor at the exploratory incision, and when it is recognized and its benignity accepted, there undoubtedly will be more cases subjected to curetting, and resection will only be done when made necessary by the complete absence of the bony shell, or when resection will leave the limb with equally good function.

My experience shows that we are seeing bone tumors of all types in an earlier stage, and it is essential that the different types be recognized at the exploratory incision.

In the contribution to the ANNALS OF SURGERY for August, 1910, full bibliography is furnished up to that date on Bone Cysts and Multiple Bone Lesions. In the article in August, 1912, some of the literature on giant-cell tumors is given. In the December numbers of *Progressive Medicine*, from 1899 to 1918, the literature on bone tumors is critically reviewed.

[23] *Johns Hopkins Hospital Bulletin*, May, 1903, vol. xiv, p. 133; *Progressive Medicine*, December, 1903, p. 201; ANNALS OF SURGERY, Aug., 1910, vol. lii, Figs. 24 to 28.

FURTHER STUDIES IN OSTEOGENESIS

By Leo Mayer, M.D.
of New York.

Despite the intensive study of bone growth called into being by Macewen's stimulating monograph [1], our knowledge of the exact changes which occur in the autogenous bone graft subsequent to transplantation, is in many respects meagre and uncertain. There are to-day at least two views relative to osteogenesis. The first, that advocated by Macewen, who maintains that osteogenetic activity resides in the bone cells, that osteoblasts pour out of the bone subsequent to injury or transplantation, and that the periosteum acts merely as a limiting membrane. The other view, dating from the classical research of Ollier (Paris, 1867) supported by the thorough experimental work of Axhausen, emphasizes the importance of the periosteum as the essential bone producing tissue. According to the first view, the bone cells live subsequent to transplantation, multiply and are capable of the same activity as transplanted epidermal cells. According to the opposing view, the bone cells die and regeneration occurs through the activity of the transplanted periosteum and of the adjacent bone into which the transplant has been inserted; in other words, the transplant acts merely as a scaffolding. This important discrepancy brings in its train other divergencies of opinion, concerning not only the histological processes, but, as a sequence of these theoretical differences, varying opinions concerning the best operative technic. Thus, for instance, Gallie believes in the use of boiled bone rather than the autogenous, living graft on the basis of the theory that the graft acts merely as a scaffolding.

It is in the hope of adding a little to our exact knowledge of the fate of the bone graft, that this paper is written. It should be of value, since the material, although limited to two specimens, has been derived not from animal experimentation, but from human autopsies.

The first specimen is from a male, thirty-nine years old, an engineer. Two months previous to his death he consulted me, because of extreme pain in the mid-scapular region. This had developed gradually, following a fall from an aeroplane about one year before. Several months previous he had been seen by a noted neurologist, who had diagnosed arthritis deformans of the vertebræ. Examination showed a very slight angular kyphos corresponding to the third dorsal vertebra. There was muscle rigidity, a zone of hyperæsthesia corresponding to the level of the kyphos, exaggerated reflexes, and hyperæsthesia of the left side below the level of the third dorsal vertebra. The X-ray showed a destructive process involving the second, third and fourth dorsal vertebræ. There were no evidences of abnormality of the ribs. The temperature ranged from 100–101°. Tuberculin test gave a positive reaction. Although a differential diagnosis between tuberculosis and malignant disease of the vertebræ could not

[1] "The Growth of Bone," Glasgow, 1912.

be made, it seemed advisable to give the patient the benefit of the doubt and treat him as though he were suffering from Pott's disease. Accordingly, the typical Albee operation was performed. The tibial graft was made unusually long (22 cm.), so as to afford rigid fixation of all the diseased vertebræ. The operation itself was uneventful. Almost immediately, subsequent to it, the patient's pain was relieved. He said that he had not felt as comfortable in many months. Four weeks later, however, he began complaining of pain in the chest and in the right thigh. Examination showed a distinct thickening of the right femur several inches below the trochanter and some thickening of the eighth right rib. X-ray showed the presence of diffuse bony enlargements, sufficiently characteristic of malignant disease to leave no further room for doubt as to the diagnosis. The patient died two months subsequent to the operation with symptoms of intrathoracic pressure.

Permission for partial autopsy was obtained. The right femur and several of the ribs showed fusiform enlargements which microscopically were diagnosed as carcinoma. The graft was found firmly healed between the cleft spinous processes. It held the vertebræ rigid and effectively prevented the collapse of the softened bodies. Its macroscopic appearance was that of dense cortical bone. At three levels cross sections of the graft and the adjacent spinous processes were removed for microscopical study.

The microscopical findings can be best summariezd by a series of illustrations: Fig. 1 is a general view of the graft and the two halves of the cleft spinous process. The periosteal surface of the graft lies toward the right side of the picture. One-half of the spinous process is in intimate contact with the graft. The other, the fractured portion of the spinous process, is separated from it by a small gap.

Fig. 2 is taken from the tip of the graft, where it projects into the soft parts. Everywhere there are evidences of bone absorption. The surface of the bone, originally smooth, has been eaten away, evidently by the ingrowth of the capillaries which are everywhere present in great numbers. All the bone cells are empty. There are no evidences of new bone formation, either from the cells of the Haversian canals or from the bone cells.

Figs. 3 and 4 are high-power views of the same area. Fig. 3 is taken from a deep portion, showing the Haversian canals full of cell detritus and a few leucocytes. Fig. 4, taken nearer the surface, shows the ingrowth of capillaries into the Haversian canals. In both pictures there is complete absence of bone regeneration.

Fig. 5, taken from that portion of the graft in contact with the cleft spinous process, shows a different picture. On the surface of the graft is a layer of young, newly formed bone, sharply differentiated from the old bone of the graft. Within the Haversian canals are seen numerous capillaries, and surrounding the canals are small areas of new formed bone. These histological facts are better illustrated in Fig. 6, an enlarged view of the preceding. It is evident at a glance that the bone cells of the graft have entirely disappeared; the lacunæ are empty. Within the enlarged Haversian canals are seen cells closely resembling the typical osteoblasts found in young, growing bone, arranged concentric to the wall of the canal with almost the exactitude of a military formation. The new-formed bone is distinguished from the original bone of the graft by a marked difference in staining quality as well as by the presence of the sharply stained bone neuclei.

From the evidence thus far presented, there seems to be no question that the graft has acted merely as a scaffolding. The bone cells of the graft have shown no activity whatever and osteogenesis has occurred only where the graft is in contact with the living bone of the spinous process. The production of new bone around the Haversian canals is logically due to the immigration of osteoblasts accompanying the ingrowth of capillaries, since on the surface of the graft, where these osteoblasts are not present, bone destruction instead of new bone formation has occurred. In the next illustration, however, evidence will be presented to show that the bone graft itself with its periosteum contributes to the osteogenesis.

Fig. 7 is taken from the periosteal surface of the graft at a point where there is no contact with the spinous process. There is evidently new bone formation along the surface of the graft, and with the high power typical osteoblastic cells are visible, ranged along the surface of the bone. Within the Haversian canals a few osteoblasts are seen and small areas of newly formed osseous tissue.

Fig. 8 shows a still greater degree of periosteal activity. This is taken from a portion of the graft near the preceding section. Here the periosteal cells have proliferated with great rapidity, as evidenced by numerous mitotic figures, and resemble young cartilage cells, such as are seen in the early stages of callus formation. There is a distinct layer of new-formed bone on the surface of the graft. These two figures speak emphatically for the activity of the transplanted periosteal cells.

In Fig. 9, which is derived from the cancellous portion of the graft, it is clear that although most of the bone lacunæ are empty, there are numerous sharply stained bone nuclei which microscopically have all the characteristics of living bone cells. It must, therefore, be assumed that some at least of the bone cells do not die subsequent to the transplantation. In other words, the graft does not act entirely as a lifeless substance, as the first sections would seem to indicate. This illustration, although showing only a small portion of the bone, is typical of all the cancellous tissue of the transplant.

The method by which the newly formed bone gradually replaces that portion of the graft which has died, has given rise to much speculation. Axhausen holds that the old bone is first eaten away by osteoclasts and is then replaced by the activity of osteoblasts. Marchand, on the other hand, insists that this process is not a satisfactory explanation and that part of the reconstruction is done by what he terms "the creeping method." In this, there is a gradual progression of new formed bone into the old, the osteoblasts acting not only to produce the new bone, but also to absorb the old. Fig. 10 is suggestive of the method by means of which the old bone is replaced by the new. It shows a portion of the graft which has already been partly replaced by new formed bone. Most of the original lacunæ are empty, but near the new formed bone are seen two lacunæ which, although within the lighter stained area characteristic of the old graft, contain sharply stained large bone nuclei. These nuclei are quite different in appearance from those seen in the previous section—survivors of the original bone. These nuclei are larger, more lightly stained and contain a distinct chromatin network. They look exactly like the young nuclei of the new-formed bone. It is also to be observed that the canaliculi connecting the lacunæ with the new-formed bone show up very sharply. It seems a plausible theory to assume that these young bone cells have passed into the empty lacunæ through the patent canaliculi.

Summarizing these microscopical pictures, we see that neither the scaffolding theory, nor the opposing view is entirely correct, but that a double process is at work; to a certain extent the graft acts as a scaffold for the ingrowth of osteoblasts derived from the adjacent bone, but it also contributes to its own life, first by the persistence of bone cells, second by the activity of the transplanted periosteum.

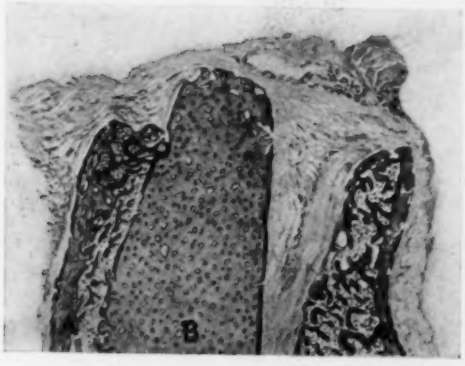

FIG. 1.—Low power view of bone graft and the cleft spinous process (first case). Note that one half of the spinous process is in intimate contact with the graft, that the other half is slightly separated from it. The right side of the graft corresponds to its periosteal surface. *A*, fractured spinous process; *B*, graft.

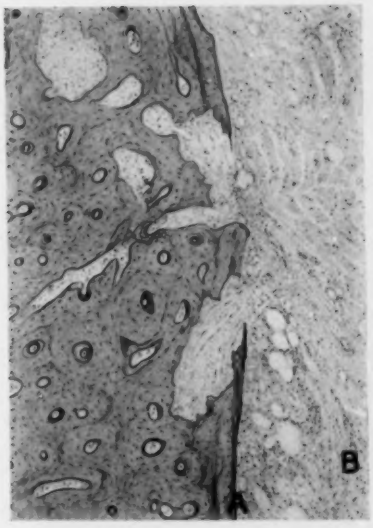

FIG. 2.—A portion of the graft near the tip where it projects into the soft parts (first case). Leitz, Obj. 1. oc. 4. Note the absorption of bone due to the ingrowth of capillaries. *A*, graft surface showing absorption; *B*, connective tissue.

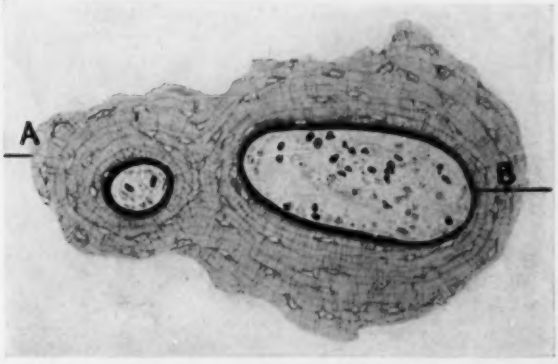

FIG. 3.—A portion of the graft near its centre (first case). Leitz, Obj. 5. oc. 1. Note that the lacunæ are empty and that the Haversian canals are filled with detritus. *A*, graft with empty lacunæ; *B*, Haversian canal with cell detritus.

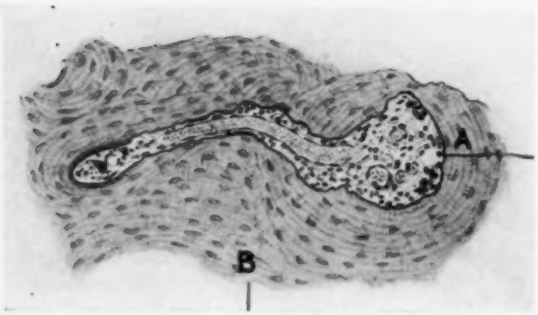

FIG. 4.—A portion of graft near the surface (first case). Leitz, Obj. 3. oc. 4. Note that the Haversian canal contains numerous capillaries, but that there are no evidences of new bone formation *A*, enlarged Haversian canal containing numerous capillaries; *B*, graft showing empty lacunæ.

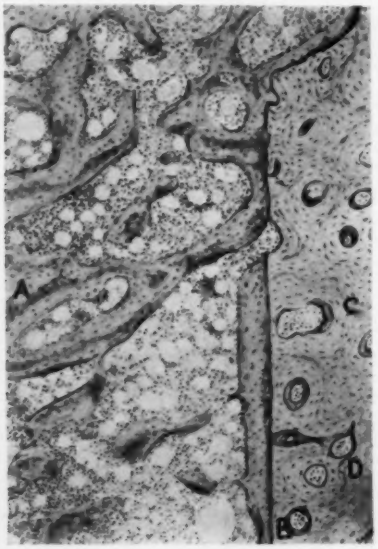

FIG. 5.—The bone graft, where it is in contact with the cleft spinous process (first case). Leitz, Obj. 3. oc. 0. Note that on the surface of the graft there is a layer of young bone differentiated from the graft by its color and by the sharply stained bone nuclei. *A*, bone lamellæ of spinous process; *B*, young newly formed bone on surface of graft in contact with fractured spinous process; *C*, young, newly formed bone about a Haversian canal.

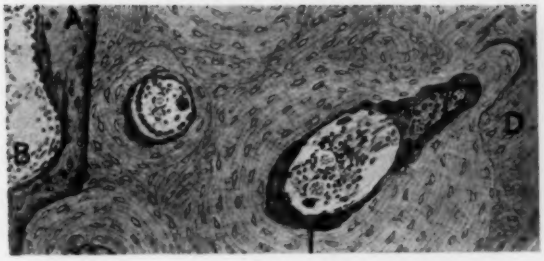

FIG. 6.—High power view of the preceding figure (first case). Leitz, Obj. 3. oc. 4. Note the formation of new bone about the Haversian canals, which contain in addition to capillaries, cells typically osteoblastic in the form and arrangement. *A*, young newly formed bone on surface of graft in contact with fractured spinous process. *B*, marrow cells of fractured spinous process. *C*, young, newly formed bone about a Haversian canal. *D*, dead bone of graft.

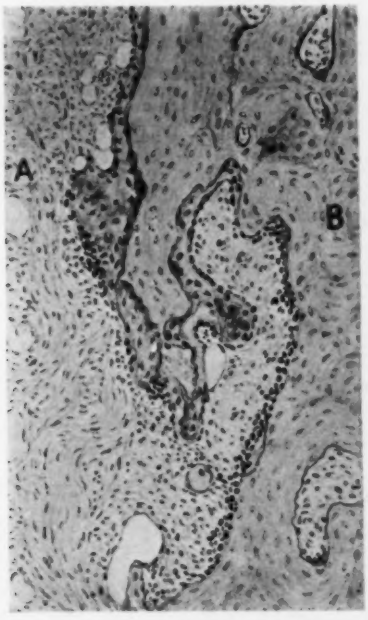

FIG. 7.—The periosteal surface of the graft (first case). Leitz, Obj. 3. oc. 4. Note the formation of new bone on the surface of the graft. This can only be due to the persistence of periosteal cells, since there is no contact with the cleft spinous process. *A*, connective tissue. *B*, graft (dead bone). *C*, young, newly formed bone on periosteal surface of graft.

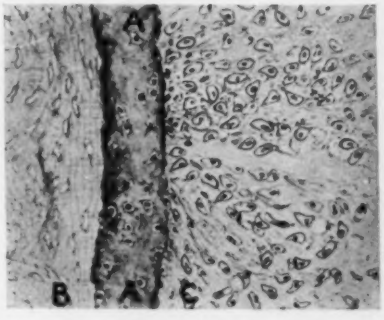

FIG. 8.—Another view of the periosteal surface of the graft (first case). Leitz, Obj. 5. oc. 0. This figure shows marked proliferation of periosteal cells with formation of young bone on the surface of the graft. *A*, newly formed bone on periosteal surface of graft (not in contact with fractured spinous process). *B*, graft showing empty lacunæ. *C*, young cells cartilaginous in morphology and staining property.

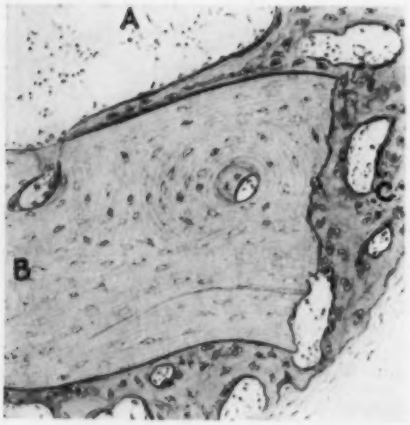

FIG. 9.—Cancellous bone of the graft (first case). Leitz, Obj. 3, oc. 4. Note the presence of numerous well-stained nuclei in the lacunæ of the graft. These cells microscopically gave all evidences of being alive, 60 days after transplantation of the bone. *A*, marrow of fractured spinous process. *B*, the graft showing numerous well-stained nuclei of bone cells. *C*, young bone on surface of graft.

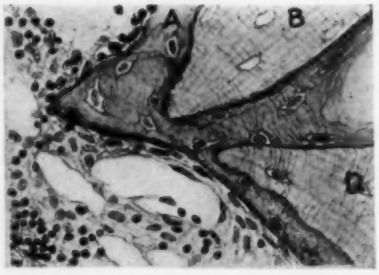

FIG. 10.—High power view of graft (first case). Leitz, Obj. 5, oc. 4. This view is suggestive of the process by which the dead bone of the graft is replaced by young living bone. *A*, newly formed bone on surface of graft. *B*, old bone of graft with empty lacunæ. *C*, marrow of fractured spinous process. *D*, old bone of graft with two well-stained nuclei of bone cells. Note the canaliculi extending from these lacunæ to the adjacent deposit of young bone. (See page 362.)

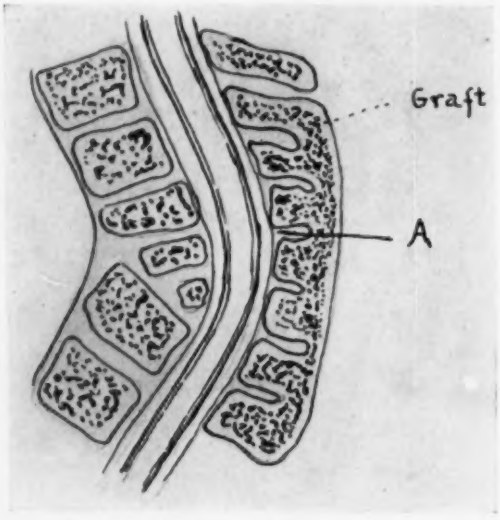

FIG. 11.—Diagrammatic sketch illustrating the appearance of the graft (second case) one and one-half years after implantation. Note the fusion of the spinous processes and the graft, so as to form a solid mass of bone. The level, *A*, indicates the site of the microscopical cross-sections illustrated in the two following figures.

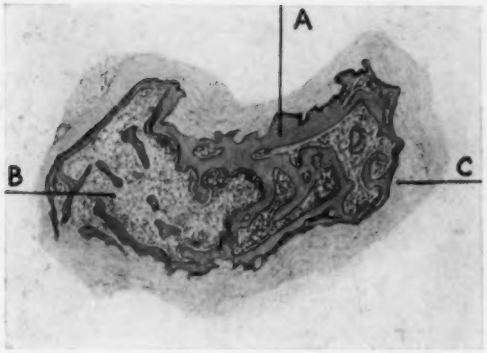

FIG. 12.—Low power view of the graft (second case) showing its conversion into a typical bone with marrow cavity, cancellous tissue and cortex. *A*, cortex; *B*, marrow; *C*, layer of tissue corresponding to periosteum.

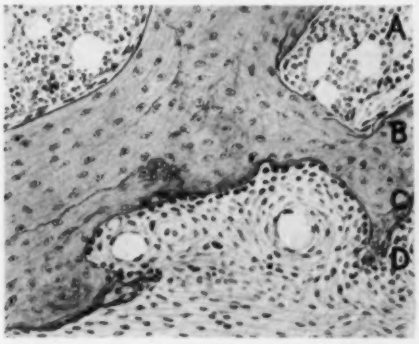

FIG. 13.—High power view of graft (second case). Leitz, Obj. 5. oc. 0. The bone cannot be distinguished from the normal structure. The marrow cavity contains typical cells. On the surface of the bone are ranged cells which morphologically are identical with the osteoblasts seen on the surface of young growing bone. *A*, marrow; *B*, cortex; *C*, osteoblasts; *D*, fibrous layer of newly formed periosteum.

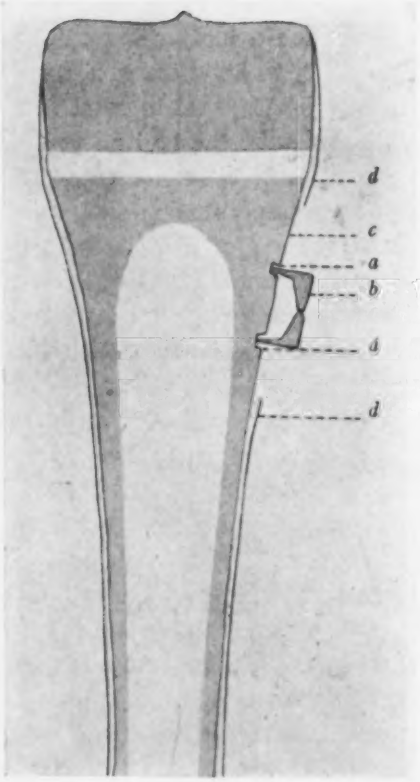

FIG. 14.—Diagram illustrating the principle of the cap experiment. *a*, groove in the surface of the tibia, into which the cap (*b*) has been implanted; *c*, surface of the bone bared of periosteum; *d*, the periosteum.

FIG. 15.—Photographs illustrating the method of attaching the caps to the surface of the tibia of a rabbit. On the left a glass cap, on the right one of steel.

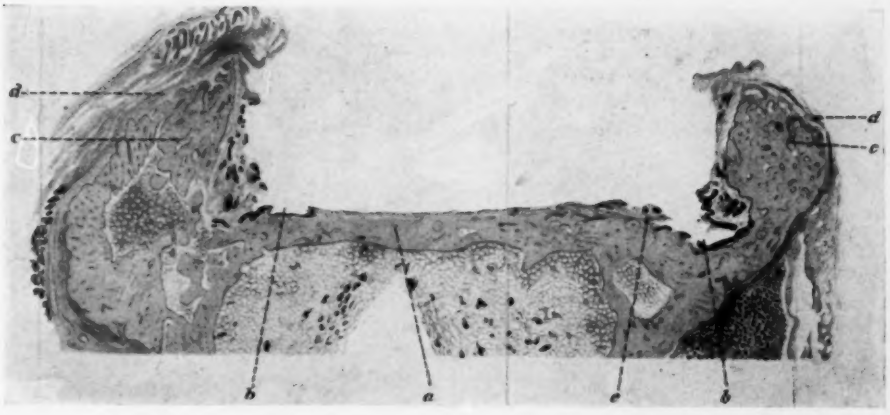

FIG. 16.—Camera lucida drawing of cross-section through the tibia, forty-eight days after implanting a steel cap. The cap effectively excluded the ingress of regenerated periosteum, therefore no new bone growth has occurred beneath the cap, whereas external to it, where the regenerated periosteum functionated, extensive new bone formation is seen. Leitz, Obj. 1. oc. 0. Tube 140. *a*, Cortex beneath the cap; *b*, the groove in which the cap rested; *c*, new bone formation external to the cap; *d*, regenerated periosteum; *e*, blood clot. (From Mayer and Wehner. Am. Jour. Orthop. Surg., Oct., 1914.)

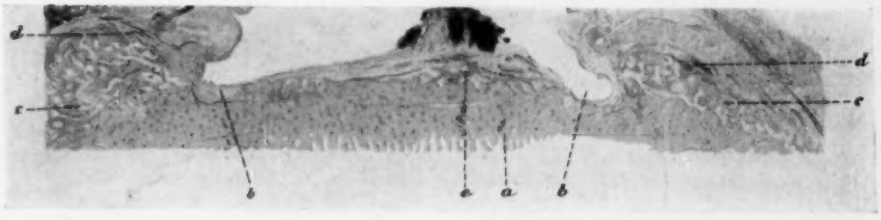

FIG. 17.—Camera lucida drawing of cross-section through the tibia fifteen days after implanting glass cap. The cap did not exclude the ingress of regenerated periosteum, therefore a new bone formation has occurred beneath it. Leitz, Obj. 1. oc. 0. Tube 140. *a*, Cortex beneath the cap; *b*, the groove in the cortex showing on the left side the ingress of periosteum; *c*, new bone formation external to the cap; *d*, regenerated periosteum; *e*, trabeculæ of new formed bone beneath the cap. (From Mayer and Wehner. Am. Jour. Orthop. Surg., Oct., 1914.)

The second specimen is derived from a case of Pott's disease in a child of nine. The typical Albee operation had been performed one and one-half years previous to the death of the patient. The child was at the time of operation in extremely poor condition; there were three discharging sinuses and a marked kyphos which had been present several years. The operation was withstood without shock, and for a time the general condition improved markedly. The sinuses, however, did not cease discharging, and there gradually developed symptoms of amyloid degeneration of the liver and kidneys, to which the death of the child was finally due. (This patient was the only one of a group of thirty in which the Albee operation failed to give an excellent result.)

At the autopsy the graft was found so firmly united to the spinous processes as to be indistinguishable from them. The sketch, Fig. 11, illustrates the macroscopic appearance of the spinous processes and the graft.

At two points sections of the graft were removed for microscopical study. A general view under low magnification is given in Fig. 12. A remarkable change in the appearance of the transplant is at once evident. Instead of a piece of solid cortex, such as was transplanted one and one-half years before, the graft has assumed the character of a tubular bone with marrow cavity, cancellous bone and cortex. In the high power view, Fig. 13, these facts are still more clearly illustrated. It is then evident that surrounding the bone there is a layer of tissue corresponding to the normal periosteum, and that on the surface of the bone are ranged numerous cells resembling the typical osteoblasts of young osseous tissue.

The cortex itself contains numerous well-stained bone nuclei lying in typical lacunæ and cannot be differentiated microscopically from normal bone. These two figures are a most interesting substantiation of Wolff's law of the functional adaptation of bone to changed mechanical conditions. The graft has assumed the peculiar form characteristic of all the long bones of the body. The specimen also gives an answer to the question so frequently put: whether the graft grows as the body increases in size. It certainly does, since it shows all the evidences of growing bone.

Although this paper deals essentially with these two autopsy specimens, it is helpful in this connection to call attention to a series of experiments performed by me during the winter of 1912.[2] In these studies, after preliminary transplantations of periosteum and subperiosteal resections, which seemed to prove the osteogenetic properties of the deeper periosteal layers, the following experiment was performed: The tibia of a rabbit or dog was stripped of periosteum over an area about one centimetre in diameter. The surface of the bone was scraped, so as to remove any adherent osteoblasts. A shallow circular groove was then bored with a trephine and into this groove a small cap of metal or glass was securely fastened (see Figs. 14 and 15). The idea was that, if, as Macewen claimed, the bone itself was responsible for osteogenesis, bone formation would occur beneath the cap; if, on the other hand, the periosteum was the vital bone producing element, bone would form on the outer surface of the cap but not beneath it. The experiment was performed on 23 animals. In more than half the cases, subsequent examination showed that minute gaps were present between the cap and the bone through which peri-

[2] Published in The American Journal of Orthopedic Surgery, Oct., 1914, and in Archiv. f. Chirurgie, Bd. 103, Ht. 3.

osteal cells had been able to pass. In nine specimens, however, the cap had effectually excluded all ingrowth. The duration of the experiments in these instances was 2, 5, 7, 7, 10, 32, 38, 48 and 55 days. "The microscopical picture was a striking negation of Macewen's thesis. The picture was always essentially the same, whether in young or old animal, dog or rabbit, with steel, nickeled or glass cap. In every instance the surface of the bone remained bare, practically as it had been left at the time of the operation (see Fig. 16). Here and there a few fibroblasts derived from the Haversian canals were seen organizing the small blood clots due to post-operative oozing. But in none of the preparations was there an outpouring of osteoblasts, in none a particle of new-bone formation, or of any sign of activity on the part of the bone cells, such as mitoses or direct cell division. Outside the cap, however, where the periosteum had been allowed to regenerate, there was always a formation of new bone, most marked in young animals and in those where glass caps had been implanted. In these cases the new bone formation was at times so extensive as completely to imbed the cap. In those instances in which a gap, however small, had been present, there was invariably some bone formation beneath the cap. This could be traced, as indicated in Fig. 17, to periosteal cells which had crept in between the cap and the surface of the bone. Although it was not our intent to leave a gap of this kind, this type of experiment was of distinct value, in disproving the view that the foreign body had acted as a deterrent to osteogenesis. Further experiments emphasized the correctness of Ollier's teaching: that the most important osteogenetic cells are those lying between the outer fibrous layer of the periosteum and the surface of the bone—the so-called cambium layer of the periosteum. The osteogenesis observed in cases of bone transplantation, macroscopically without periosteum, is unquestionably due to the adhesion of these osteogenetic cells to the surface of the graft. Endosteal cells of the marrow cavity and of the Haversian canals are also capable of osteogenesis, though to a diminished degree."

SUMMARY

Study of two specimens recovered at autopsy, together with extensive animal experimentation, show that the fully developed bone cell has no power of division and that bone growth results from the activity of cells lying between the bone and the outer layer of the periosteum. The cap experiments prove that, when these cells are removed, the bone itself is not capable of reproducing them, but that the periosteum has that power. In transplantations, the bone graft acts partly as a scaffolding for the ingrowth of osteogenetic cells, but it contributes also to its own life, first by the persistence of some of its bone cells, second by the activity of the transplanted periosteum. The graft grows in its new situation and becomes modified in its form according to the changed mechanical conditions. (Wolff's law.)

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EFFACEMENT OF CAVITIES IN THE TREATMENT OF FRACTURES

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A "DEAD SPACE" between the tissues plays a very important part in infection. This has been very well demonstrated by the post-operative course. If during an operation a free space is left between two layers of tissue, this space will become filled with blood or serum. This hæmatoma, if the wound remains sterile, becomes encysted and is progressively reabsorbed. But, if a sufficient number of virulent bacteria have contaminated this cavity, suppuration transforms the hæmatoma into an abscess. It seems that these so evident facts have not been sufficiently emphasized, as a fundamental principle, in the surgical treatment of fractures. Cavities have been drained, but sufficient attention has not been paid in operating on infected fractures to efface the cavities formed by the displacement of the fragments.

Looking at the Fig. 1 representing a fracture of the femur with lateral displacement, the periosteum is seen very plainly bridging over each end, forming a more or less triangular cavity, formed on two sides by the bone surfaces and on the other by the periosteum.

These two cavities become filled with blood which soon will be infected and the infection in turn will disturb the formation of new bone and the cicatrization of the two ends progresses poorly. As Guillot and Woimant have shown,[1] in these cases of infection the extremity of the medullary canal does not become plugged and the vitality of the compact bone is diminished.

We have frequently controlled the truth of this assertion and there does not remain the least doubt in our minds of the necessity of removing at the operation all dead spaces, at least, when it is not possible to obtain this effacement of the cavities with more simple means as the external application of pressure on the soft parts of the limb in the region of the line of fracture. From this point of view Doctor Dehelly thought that the bridged plaster casts and the apparatus immobilizing in traction and suspension, such as the Thomas or the Blake splints, have the great drawback of not permitting the compression of the focus of fracture.

[1] Guillot and Woimant, Surgery, Gynæcology and Obstetrics, November, 1917; Revue de chirurgie, January-February, 1917.

Each time that after sterilization of a fracture of the femur we have used the Hennequin apparatus (Figs. 2, 3 and 4), we have obtained much better results. Here is an example already published in Doctor Dehelly's book with Carrel (Figs. 5 and 6).

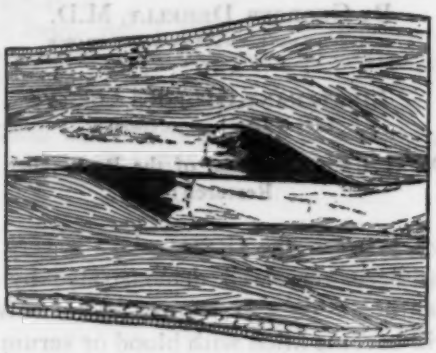


FIG. 1.—Fracture of femur with overriding fragments.

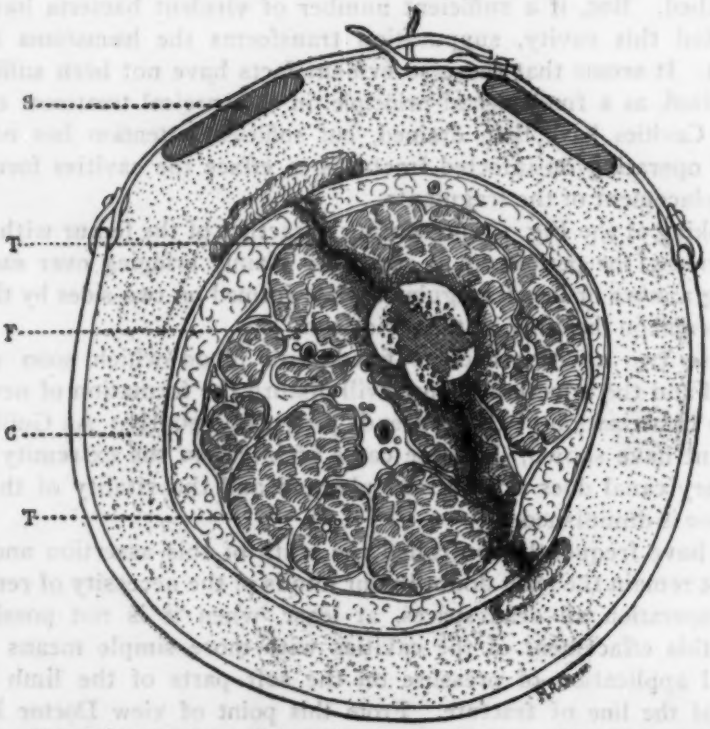


FIG. 3.—Hennequin apparatus applied loosely. Compound fracture of femur seen on section of the thigh. *S*, wooden splint; *T*, tract of wound (shell) after sterilization and secondary closure; *F*, focus of fracture with scattered fragments; *C*, surgical cotton pad, as cushion.

This case arrived at the hospital seven hours after having been struck by a shot which produced an extremely comminuted fracture of the left thigh.

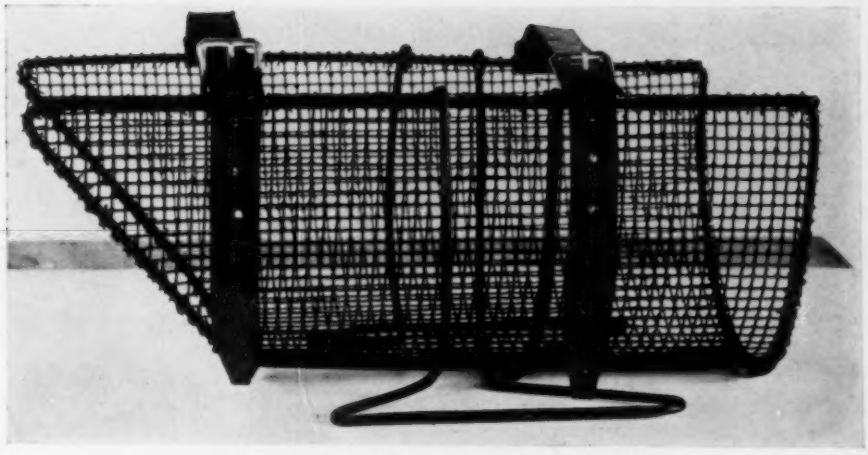


FIG. 2.—Hennequin apparatus for treatment of fractures of femur.

FIG. 5.—Comminuted fracture (fresh) of the middle third of femur, with bullet present.

FIG. 6.—Only two small splinters removed. Good alinement with firm callus obtained by the use of compression of the focus of fracture with the Hennequin apparatus.

The diaphysis of the femur had been broken at the level of its middle third into multiple fragments. After cleansing of the contused soft parts two small splinters, completely free, were removed. The fifteenth day, after sterilization, the wound was closed. A good alignment with firm callus was obtained by the use of *compression of the focus of fracture with the Hennequin apparatus.* The fracture was firm on the forty-seventh day.

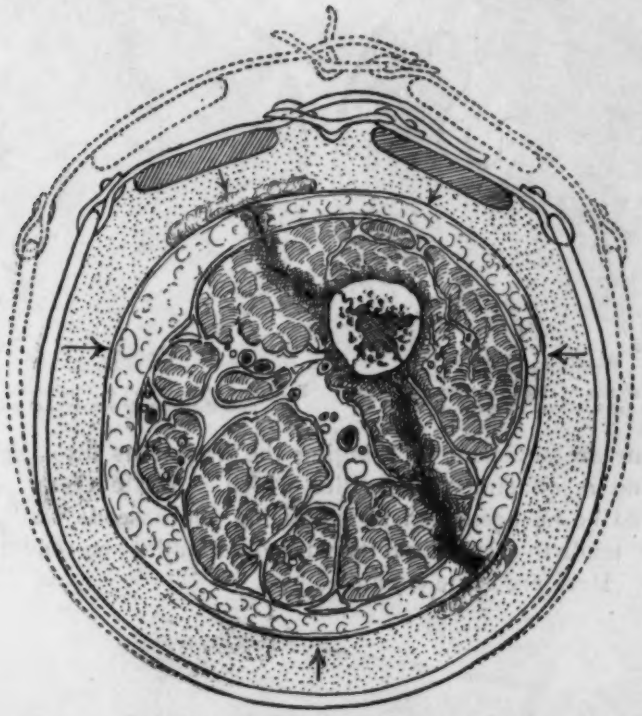


FIG. 4.—Apparatus tightened, showing the bringing together of the bone fragments by pressure of the apparatus. The wooden splints force down the upper fragment which usually tends to lift itself.

Before taking up in detail the different types of cavities which may be observed, let us state a few general rules of surgical technique:

1. The operation itself must not create a cavity in or near the bone.

2. Two overlapping fragments must not be cut perpendicularly to the axis of the bone (Fig. 1).

3. When a long bone is guttered not one but three sides must be removed (Figs. 7 and 8).

In the treatment of fractures several periods must be considered:

1. Immediately after the wound.
2. During the period of acute infection.
3. When consolidation has begun.
4. During the period of fistula.

1. *Immediately After the Wound.*—During the first intervention, the indication of an operative procedure on the bone is less imperative than later because the surgeon may hope and must count on the reduction of fracture by continuous extension with limb in good position; and we can state that very often, especially when external pressure was applied, these

FIG. 7.—Cross-section of thigh showing usual guttered femur (insufficient removal of bone).

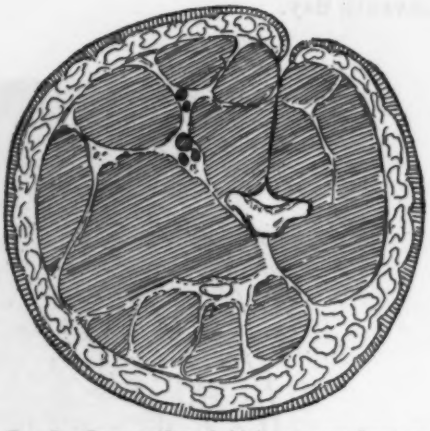


FIG. 8.—Cross-section of thigh—one quadrant remaining; proper removal of bone.

means alone are sufficient in bringing the fragments into their normal position and in effacing the cavities which separate them. However, there should be no hesitation in sacrificing the osseous wall which by its position tends to create a cavity with rigid wall when reduction is not obtainable. Here are some examples.

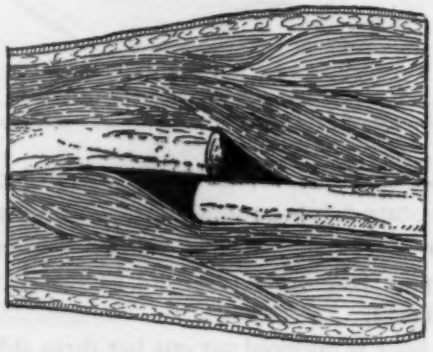


FIG. 9.—Fracture of femur unreduced—insufficient removal of bone.

(a) The loss of substance between the two fragments has left two ends cut nearly perpendicularly (Figs. 1 and 9)—between them a space persists which can be filled by a new bone only after a long time, and which cannot be effaced by the approximation of the periosteum and the soft parts. It is preferable to sacrifice one wall of the two fragments in

order to allow the apposition of the soft parts, care being taken of preserving the periosteum (Figs. 10 and 11).

(b) Long bevelled fragments form between them dead spaces of various shapes. In Fig. 12 two cavities are produced, the upper one triangular, the inferior one more elongated. This drawing was made from

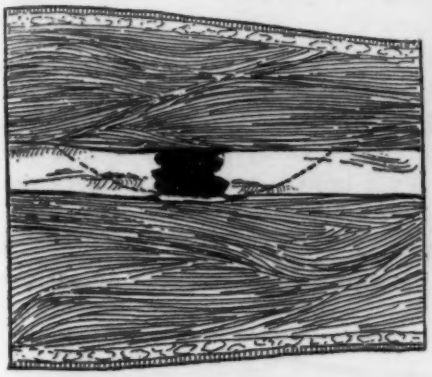


FIG. 10.—Transverse fracture; dotted line showing bone to be moved.

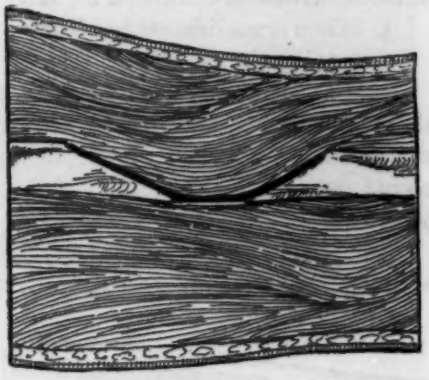


FIG. 11.—Same as Fig. 10, after operation.

an X-ray picture of a wounded soldier for whom two operations were necessary, one on each cavity, in order to obtain the cure. It was necessary to bevel the two extremities and to keep only the two parts of the extremities which were in contact (Figs. 13, 14 and 15).

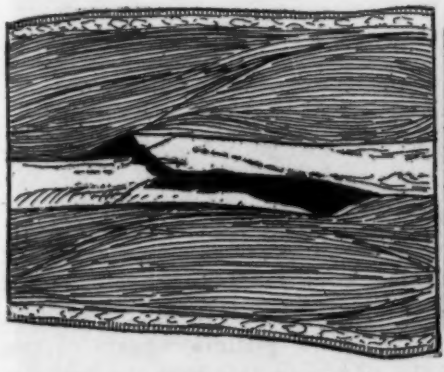


FIG. 12.—Long bevelled fracture of femur, dotted lines indicating projecting fragments of bone to be removed.

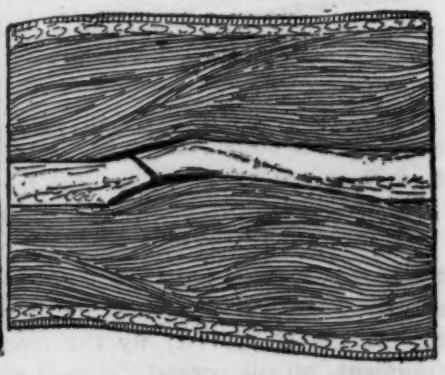


FIG. 13.—Same as Fig. 12, after operation, the soft parts filling the cavities.

(c) In this case we have two overlapping fragments of a transverse fracture (Fig. 9). The picture shows the two large cavities produced. If simple reduction is impossible the operation must consist in the removal of all the projected portion of the two fragments—only the points where the bones are in contact ought to be kept (Figs. 16 and 17).

2. *During the Period of Acute Infection.*—At the phlegmonous period it is more prudent not to treat these cavities in the manner described above. Above all they must not be ignored. They must at least be opened and instillating tubes must be inserted in order to carry out Carrel-Dakin method. This primary disinfection will place the tissues in more favorable condition for later adequate operation.

3. When consolidation has begun.

4. During the period of fistula.

The operation which we have recommended for the fresh fracture should be performed, but at these two periods when union has begun and during the period of fistula, care should be taken to preserve the points where the bone has united, because union occurs only where the bone is healthy.

One must not always reach the bone through the classical approach but sometimes it is better to reach it perhaps through the less accessible

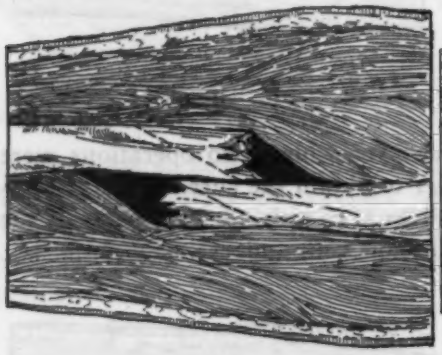


FIG. 16.—Overriding fracture of femur, showing the proper operation.

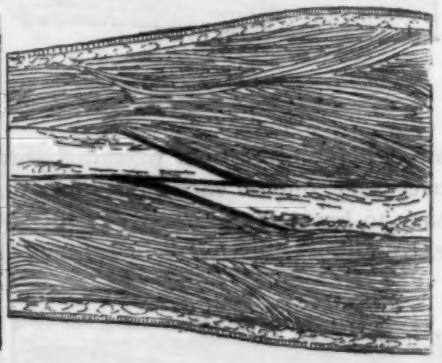


FIG. 17.—Same as Fig. 16, after operation.

aspect, but in such a manner as to attack the most pathological side of the fracture.

The following example illustrates this point:

A fracture of the tibia with a large loss of substance from the posterior aspect is united by a large anterior consolidating splinter. It is evidently important to keep the large anterior consolidating splinter and to "efface" the cavity by the resection of the posterior parts of the fragments on the posterior aspect of the tibia. In this case the incision must be made on the inner aspect of the leg, behind the inner border of the tibia, and it is easily seen that the new sloping cavity will be filled snugly by the soft parts of the posterior region of the leg (Figs. 18 and 19).

In the same manner, when after the first operation a new abscess develops, one must avoid, if the bone has been previously opened through the classical approach, operating through the same incision. It is most important that the most pathological side of the bone be reached with-

FIG. 14.—Compound oblique fracture of middle third of femur with chronic fistula. The plate shows lateral displacement of the fragments and the formation of a cavity with pus; indicated by the arrow. Also two small sequestra.

FIG. 15.—Plate shows same after treatment; the cavity has been suppressed by the removal of the projecting bone fragment and loose fragments.

FIG. 18.—Compound comminuted fracture of the upper third of the tibia, with loss of bone tissue of the posterior aspect, creating a dead space.

FIG. 19.—Removal of the upper and posterior aspect of the lower fragment of the tibia, showing the sloping cavity which can be filled in by soft parts.

out compromising the healthy parts indispensable for the solidity of the limb.

In doing this we have sufficient to spare because as we have already said it is enough to keep one of the sides of the osseous circumference. The thing to be avoided is to keep the infected side and this may happen if, before the operation, the localization of the pathological side has not been possible. In this case the bone is reached by the classical approach and the tendency is to remove the sides of the bone which are most accessible. This may be a mistake if the posterior quadrant is exactly the one which is the site of osteitis and which should be removed.

In the case, for instance, of a tibia which has been opened (Fig. 20) but which continues to suppurate because the posterior surface is the seat of osteitis, it is evident that in the operation one of the two surfaces, the internal or the external, must be conserved for the continuity of the bone; the quadrant of choice to be removed is that one which will allow

FIG. 20.—Usual insufficient operation on tibia, the lateral walls preventing apposition of soft parts.

FIG. 21.—Walls removed, allowing soft parts to approximate.

the soft parts to fill up the space most easily. In the case of the tibia it is better to keep the external side and to remove the internal, because when the external side is removed, the fibula prevents the soft parts from filling the dead space (Fig. 21), whereas there is nothing which prevents the internal tissues from coming in good position to obliterate the cavity after the internal side has been removed (Figs. 22, 23 and 24).

The cavity may be due to a peculiar formation of the callus—a fracture of the femur made by gunshot wound was united by a circular callus leaving a cavity with sequestra in the centre.

Three months after the wound was inflicted there was a sinus with large amount of discharge. An incision made through the old external wound down to the bone revealed a callus formed of two bridges of new bone, a large internal and a smaller external one. This cavity, so limited, communicated externally with a dead space in the external portion of

the thigh. The outer bridge of the callus was cut away with a chisel as were also the blunt ends of the upper and lower fragments. This allowed the whole cavity to collapse and the soft parts to come into apposition (Figs. 25 and 26).

FIG. 22.—Removal of internal and posterior side of tibia through usual anterior incision, with incomplete approximation of skin.

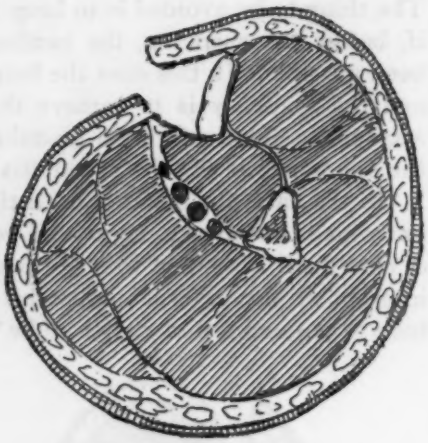


FIG. 23.—Proper incision.

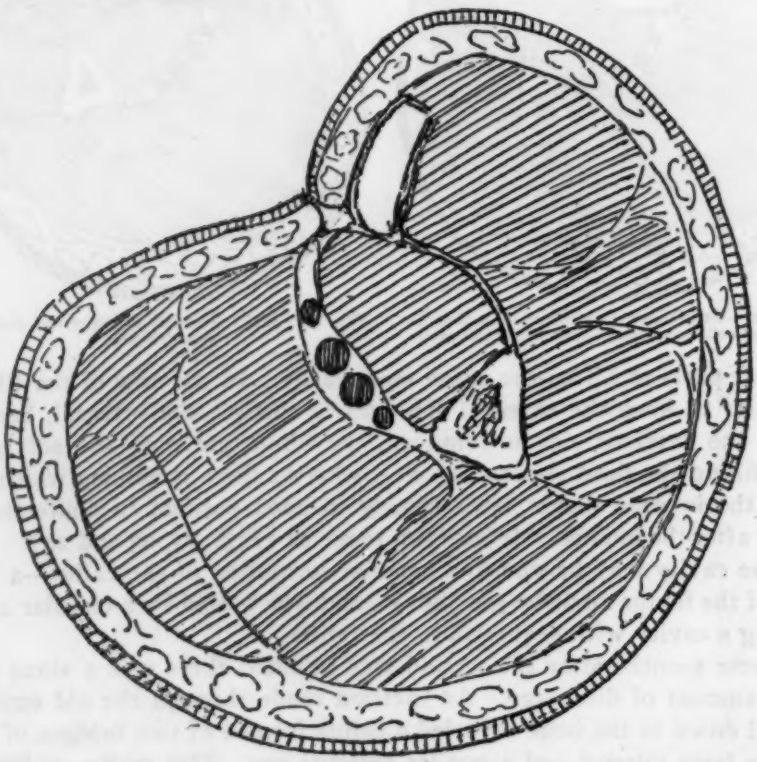


FIG. 24.—Same as Fig. 23, with obliteration of cavity by means of proper incision.

Interventions for the Purpose of Effacing Bone Cavities are not Necessarily Confined to the Bone.—There are cases (fracture near a joint) where it is impossible to bevel the cavities for fear of opening the joint. For instance, in a case of supramalleolar fracture of the tibia (Fig. 27), it was not possible to obliterate the cavity by plastic confined to the bone, but,

FIG. 25.—Fracture of femur, middle third, united by circular callus, showing cavity with two sequestra. Chronic fistula. *A*, *B*, extent of bone tissue removed.

after sterilization the cavity was obliterated with a pedunculated flap taken from the adjacent skin, with its underlying subcutaneous tissue being used to fill the cavity (Figs. 28, 29, 30 and 31).

In a case of fracture of the neck of the humerus with large loss of bone substance after union the cavity was satisfactorily filled with Beck's paste and closed with two layers, muscle and skin.[2] One may also in a simple but less elegant manner, slide into the bottom of the cavity a pedicle of skin and underlying subcutaneous tissue without suturing. Or, still, as we have done, shift one border of the wound with a bridge of

[2] This case has been published in "Treatment of Infected Wounds," Carrel and Dehelly, p. 203.

tissue, instead of a pedicle, and hold it in this shifted position by means of packing so as to place immediately on the front of the bone skin reinforced with its cellular tissue instead of allowing the epithelium simply to cicatrize (Figs. 32 and 33). This leads us to remark that the proper placing of the packing may contribute to the effacement of the dead spaces but that unfortunately they may also contribute to their formation.

In the two preceding cases of pedunculated flap and skin for the purpose of approximating it to the bony surface, it is necessary to obtain sterilization of the wound, and second, to maintain the flap in good posi-

FIG. 26.—Schematic longitudinal section of the same with bone tissue removed and soft parts suppressing the cavity. Rapid healing.

tion with the proper dressing. In these cases, it is advantageous to apply elastic traction lacing for two days previous to the operation. This allows the shifting of the skin at the time of operation. Sometimes if the operation has been done in an aseptic wound and the effacement of the cavity practised, the wound can be closed and the compression made immediately.

The preceding case is one which was due to the dressing. The opera-

FIG. 27.—Old fracture of the lower third of the leg. Large callus and a bone cavity in the tibia which was filled with adipose tissue.

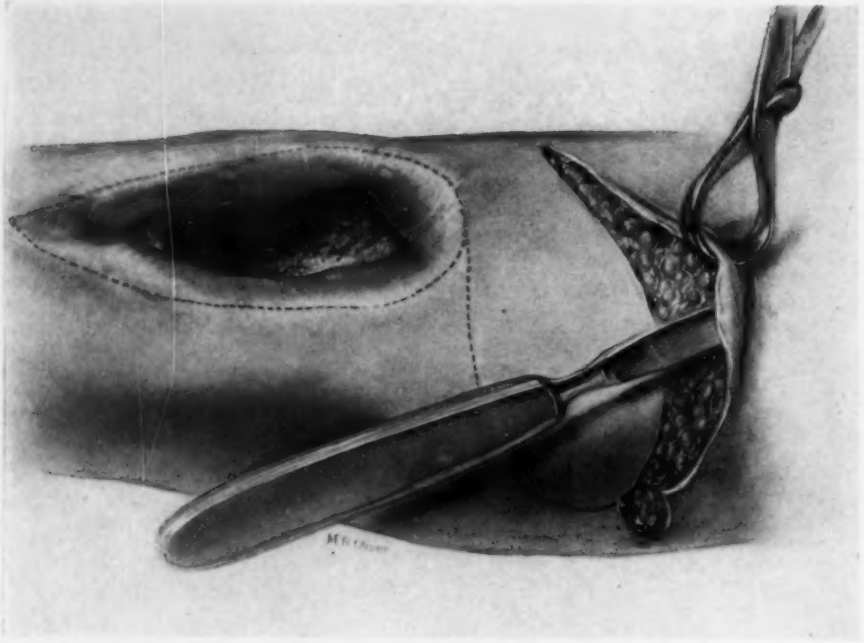


FIG. 28.—Skin flap with adipose tissue. The fat is removed subcutaneously by undermining the surrounding skin. Dotted line shows excision of scar and incision for skin flap.

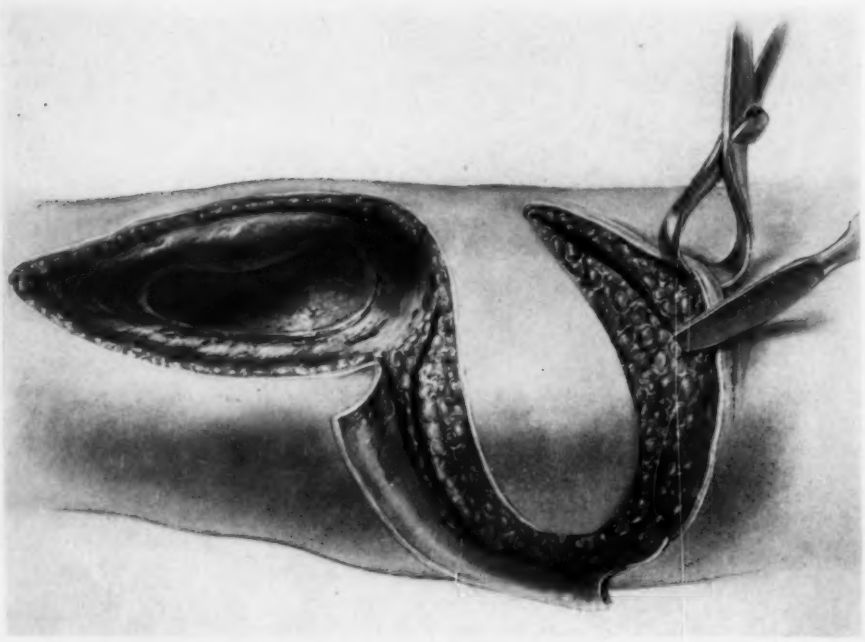


FIG. 29.—After undermining skin, fat flap is made by an incision to the aponeurosis, at some distance from the skin edge of flaps.

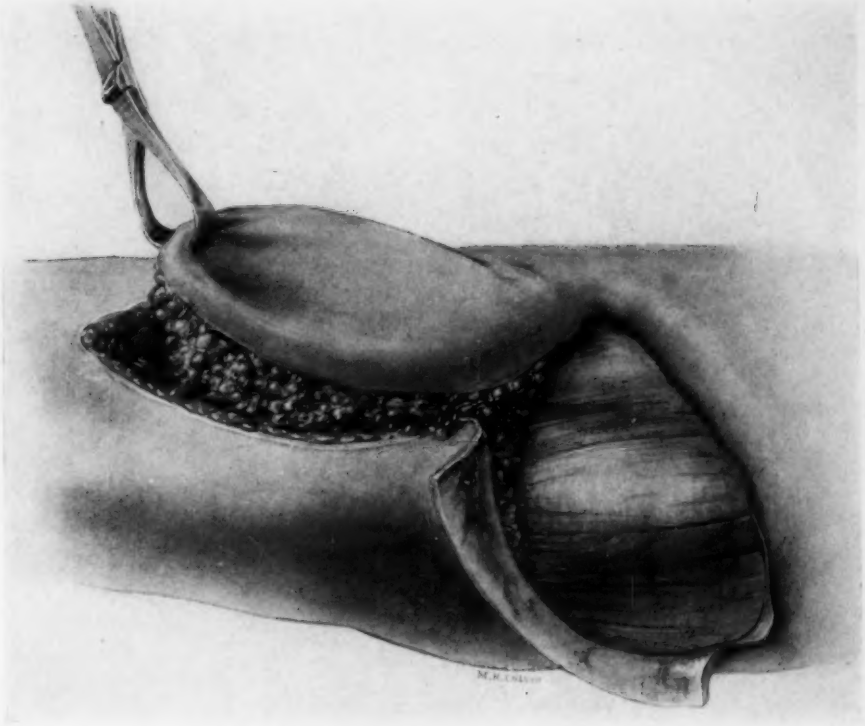


FIG. 30.—Flap turned, the fat filling the cavity.

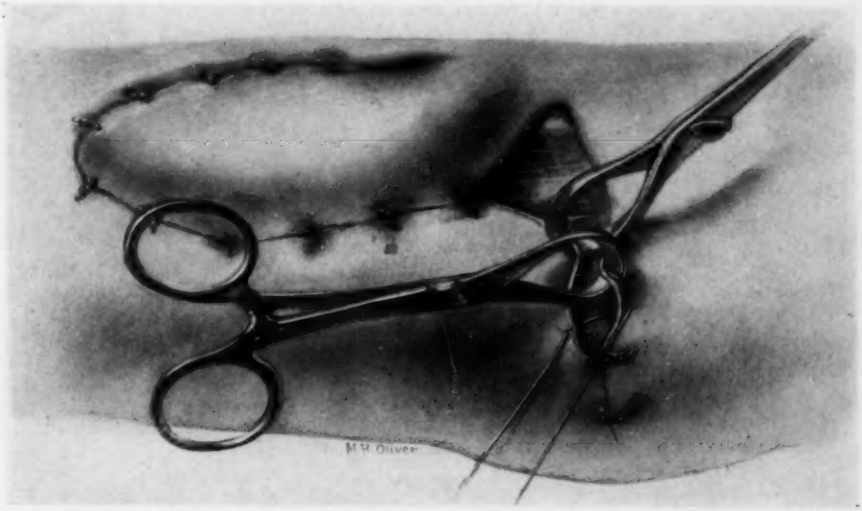


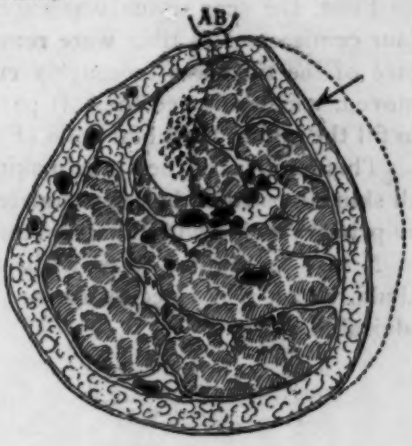
FIG. 31.—Closure with suture, leaving a small area uncovered, which will heal by granulation or with skin graft.

FIG. 34.—Compound fracture, middle third of leg. United chronic fistula; a narrow bridge of callus joins the two fragments. This bridge creates a cavity between it and the tibia, which space was responsible for the fistula.

FIG. 35.—Removal of the bridge of bone, suppression of the cavity by approximating the soft parts to the bone. Healing by first intention.

FIG. 32.—Fracture of tibia with loss of substance of skin.

FIG. 33.—Plastic operation—a bridge of skin and subcutaneous tissue shifted laterally to obliterate cavity.



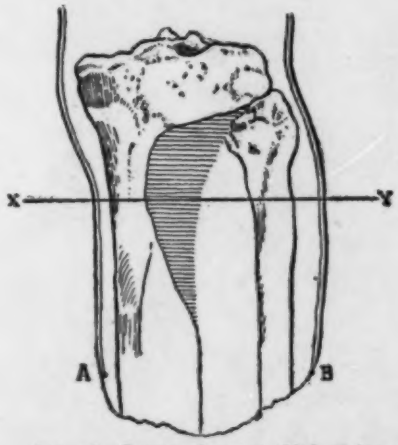


FIG. 36.—Stump of upper third of leg. Chronic fistula connected with a cavity on the outer and posterior aspect of the tibia. *X—Y*, cross-section through cavity; *A—B*, line of incision beyond scar tissue.

FIG. 37.—Removal of fibula, the soft parts suppressing the cavity. Healing by first intention. *X—Y*, cross-section through site of cavity, fibula removed, cavity suppressed by approximating soft parts; *AB*, line of incision.

tion has been performed correctly, the cavity well bevelled, but the periosteum had been continuously separated by the packing. As a result a rigid walled cavity, which prevented the approximation of the soft parts, was formed (Fig. 34). In this case the final operation consisted in simply removing the bone from the external wall and in pressing the soft parts toward the tibia (Fig. 35). Healing was obtained by first intention.

An operation following the same principle was performed in a case with a short stump of the leg after a guillotine amputation through the middle third. Perfect result was obtained by Doctor Dehelly.

This patient arrived with a large granulating wound of the stump with bones exposed and a discharging sinus leading to a *cavity* due to the destruction of the external and posterior surfaces of the tibia. There was a choice between a disarticulation through the knee-joint or a plastic operation. After sterilization, with Doctor Carrel's method, the latter operation was performed.

First, the scar tissue was excised with the granulating surface and four centimetres of tibia were removed. The cavity of the external surface of the tibia was thoroughly curetted, and the fibula was entirely removed, which allowed the soft parts of the external aspect of the stump to fill the gap in the tibial bone (Figs. 36 and 37).

This removal of the fibula making the stump smaller in circumference, all skin edges could be approximated and sutured. Healing was obtained by primary union with a useful stump.

NOTE.—In similar cases with stumps of the leg, the removal of the fibula, which is not necessary for the solidity of the stump, seems to be advisable.

SYNTHETIC TRANSPLANTATION OF TISSUES TO FORM NEW FINGER

WITH RESTORED FUNCTION OF HAND

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Among the cases of war injuries under plastic treatment at U. S. Army General Hospital No. 3, the value of tissue grafting has been strikingly illustrated in two instances which are unique in the author's experience. In each case, severe laceration of the hand by high explosive shell and shrapnel had necessitated the immediate amputation of the four fingers with all, or the greater part, of the adjoining metacarpal bones. When the patients first came under observation, several months after injury, the stumps were healed and the thumbs were of normal strength and flexibility. All function as a hand had, however, been practically destroyed in each instance, since the thumb, the only remaining digit, had no power of prehension, in the absence of any opposing surface.

As an alternative to the fitting of artificial appliances, an entirely new digit was constructed by means of synthetic transplantation of tissues. This "finger" has provided in each instance the necessary opposition to the thumb, transforming the hither-to helpless stumps into useful members.

DESCRIPTION OF CASES

Case I.—J. W., aged thirty years, sergeant, Co. K, 9th Infantry, A. E. F., sustained a severe shell wound of the left hand on June 11, 1918, at Château-Thierry. Amputation of the four fingers with the adjoining metacarpal bones was performed at the evacuation hospital where the last dressing was recorded on July 11, 1918. When admitted to U. S. Army General Hospital No. 3, on October 4, 1918, the stump was entirely healed and the thumb was of normal strength, with no contraction nor stiffness. The patient was, however, powerless to grasp and hold objects with the injured member, because of the lack of an opposing surface for contact with the thumb (see Fig. 1).

In the aim of a more complete restoration of function of the hand than could be obtained by a resort to artificial appliances, the construction of a new digit by tissue grafting was undertaken with the hearty coöperation of the patient. The first operation, by the Italian plastic method, was performed on December 27, 1918.

First Step.—After preparing the fields of operation with iodine technic, a rectangular skin flap, 2½ x 3 inches, including full thickness of skin and subcutaneous tissue, was turned up from the right chest wall and sutured into the form of a finger. Its pedicle, the full width of the base, was left attached to the right side to supply nourishment to the boneless finger. The portion of chest wall left uncovered by the removal of the graft was closed by swinging plastic skin flaps, black

silk being used for suture material. (For operative steps, see Fig. 2.)

Second Step.— An incision was then made on the stump surface of the hand over the os magnum and extending down through the soft tissues nearly to the bone. To these soft parts was sewed the cuff of skin forming the boneless finger, great care being taken to secure exact approximation of corresponding layers of graft tissue to host tissue, *i.e.,* skin to skin and subcutaneous tissue to subcutaneous tissue. (It is as important to observe these relations in the transplantation of soft tissues as it is in the grafting of bone.) In order to avoid traction upon the boneless finger, the hand was then immobilized by means of incorporating the shoulder, arm and chest in a plaster-of-Paris spica, the axilla having first been thoroughly padded with cotton. The thumb was left projecting in order to determine the circulation of the limb (see Fig. 3).

Four weeks later, on January 24, 1919, the second operation was performed.

First Step.—After removing the case, the hand and boneless finger were disengaged from the thoracic wall by dissecting loose a circular flap of skin 1½ inches in diameter, in addition to the finger portion.

Second Step.—The anterior internal surface of the upper portion of the left tibia was laid bare by a curved incision about five inches in length. A graft three inches long and about ⅜ inch wide was mapped out with the scalpel in the periosteum, one end being cut wedge-shaped. Following the indicated pattern, saw-cuts were then made with the author's motor saw completely through the cortex to the marrow cavity. For purposes of "bone-seed," or increased osteogenesis, a sliver graft about $\frac{1}{16}$-inch in diameter was removed from the side of the gutter formed by the removal of the first graft. Both grafts consisted of the full thickness of the periosteum, the cortex, the endosteum and as much of the marrow substance as could be obtained, *i.e.,* as much as clung to the graft when it was pried out of its bed. These grafts were then dropped into a normal saline solution of about 40° C., while the new bed of the graft was being prepared.

Third Step.—Now the boneless finger was tunneled by means of a small scalpel down to the os magnum. With an osteotome, a wedge-shaped mortise ⅜-inch deep was made in the distal-radial surface of this bone. The large graft was then taken from the salt solution and with a mallet its wedge end was driven into the mortise just made in the surface of the os magnum until it became firmly engaged in the cancellous structure of this bone. The sliver graft was thrust through the soft parts of the boneless finger along the ulnar side of graft No. 1, and, by means of the author's "bone-set," its end was affixed in the mortise already mentioned. (For position of the bone grafts, see radiogram, Fig. 4.) The end of the graft was then covered by means of the circular skin flap referred to above and sutured over to form the end of the new finger. The hand and finger were immobilized by means of a metal splint and left undisturbed for four weeks.

Convalescence was uneventful, primary union taking place in all steps. In Fig. 5 is shown the new finger after the removal of the splint, four weeks after the implantation of the bone graft. The patient was now able to pick up sponges and towels with his thumb and grafted finger and an X-ray examination made at that time showed the transplanted parts firmly united to the bone of the hand (see radiogram, Fig. 4). With increasing strength and dexterity of the repaired hand, the patient has recovered his ability to perform the ordinary acts of every-day life, as is demonstrated in Figs. 6, 7 and 8. The helpless stump has been transformed into a useful member, capable of most of the necessary functions of a hand.

Aside from the favorable sequence of restored function, this case presents the personal history of a soldier in the U. S. Army of considerable interest. A native of Belgium, the patient was left an orphan at eleven years of age and was obliged to earn a living for himself. He spent an early life of varied occupations, serving as bell-boy, waiter, maître d'hôtel in Paris, interpreter in Switzerland and mail-carrier in Belgium. In 1913, he came to the United States (receiving citizenship here some time later) and worked as a day-laborer, boss of a railroad construction gang in the Canadian Northwest and later as fur-trapper. He had served in the infantry of the A. E. F. for a year and a half when he was injured while on duty at Château-Thierry.

Since his arrival at U. S. Army General Hospital No. 3, the patient has not only shown a remarkable coöperation in every effort made to improve his physical disability, but he has availed himself enthusiastically of the privileges offered at the hospital school, opportunities for study of which he was deprived in his earlier life. In spite of two operations, he has missed but five days of school during the period of his residence at the hospital and ranks first in scholarship and attendance among a total of 622 enrolled patient-students. At all hours of the day, when it is permitted to leave his ward, he is to be found at the school, where he is studying English and mathematics in the hope that eventually he may fit himself for some specialized work, such as surveying, or forestry, in which he is extremely interested, but which lack of training has thus far made impossible.

The case of this patient is illustrative of many convalescent cases at the hospital, in which careful advice as to future industrial occupation is being given and a preliminary instruction at the hospital school begun, with a view to a possible specialized training later under the auspices of the Federal Board for Vocational Education. In this case, the patient has been advised to take up forestry or engineering. During his convalescence he has made rapid progress in mathematics and English and allied subjects, all of which are building toward a future specialized training.

Case II.—C. C., aged twenty-nine years, private, Co. D, 2nd Engineers, A. E. F., was struck by shrapnel causing severe laceration of the

right hand on June 13, 1918, at Château-Thierry. Amputation of the four fingers with the greater portion of the adjoining metacarpal bones was performed on the same day, the skin flaps being left open until July 15, 1918, when the wound was sutured and immediately healed by primary union. The patient was admitted to U. S. Army General Hospital No. 3 on October 4, 1918. In his case the indications for operative interference were the same as in Case No. 1. The strength and flexibility of the thumb were unimpaired, but in the absence of an opposing surface it had no power of prehension. In this case, however, it will be noted that the proximal heads of the metacarpals had not been destroyed. As shown in Fig. 9, the gap between the thumb and the amount of stump remaining was correspondingly less than in Case I. (Compare Fig. 1.) A shorter digit was required, therefore, in this case, to complete the stump surface and furnish the necessary contact with the thumb.

On December 24, 1918, the first operation in the construction of a new finger was performed. It was decided to obtain the bone graft from the left clavicle and the soft parts from the skin and subcutaneous tissues overlying.

First Step.—A rectangular flap of skin, 3 inches long and 2½ inches wide, was turned up with the pedicle toward the left shoulder, exposing the middle third of the clavicle. With the author's motor saw an anterior portion of the clavicle, 2¼ inches in length and comprising about one-third of its diameter, was cut wedge-shaped at one end and so removed as to include the periosteum, the full thickness of the cortex and a considerable amount of marrow substance.

Second Step.—This graft was allowed to lie in the wound while an incision over the stump surface of the hand laid bare the distal end of the head of the metacarpal bone of the third digit in which a wedge-shaped mortise about ⅜-inch wide was made by means of an osteotome. The graft was then taken from its bed and with a mallet its wedge end was driven into the mortise just made. (For position of bone graft, see radiogram, Fig. 12.)

Third Step.—The rectangular skin flap with pedicle, turned back at the first incision, was then approximated in cuff shape about the graft and to the edges of the incision in the hand. The pedicle at its base was left attached to the neck to furnish nourishment to the graft tissues until circulation with the hand should be thoroughly established in the newly implanted parts. (For position of hand and grafted finger, see Fig. 10.) By plastic skin flaps the exposed surface of the clavicle was entirely covered, sutures of black silk being used. A generous cotton padding was then placed between the arm and the forearm and the chest wall. The hand was immobilized and undue tension upon the new finger was prevented by a plaster-of-Paris spica, as shown in Fig. 11.

On January 23, 1919, the plaster bandage was removed and the newly made finger and hand were disengaged from the neck in such manner as to leave an additional circular flap of skin about 1¼ inches in diameter at the end of the finger. This flap was later sutured so as to

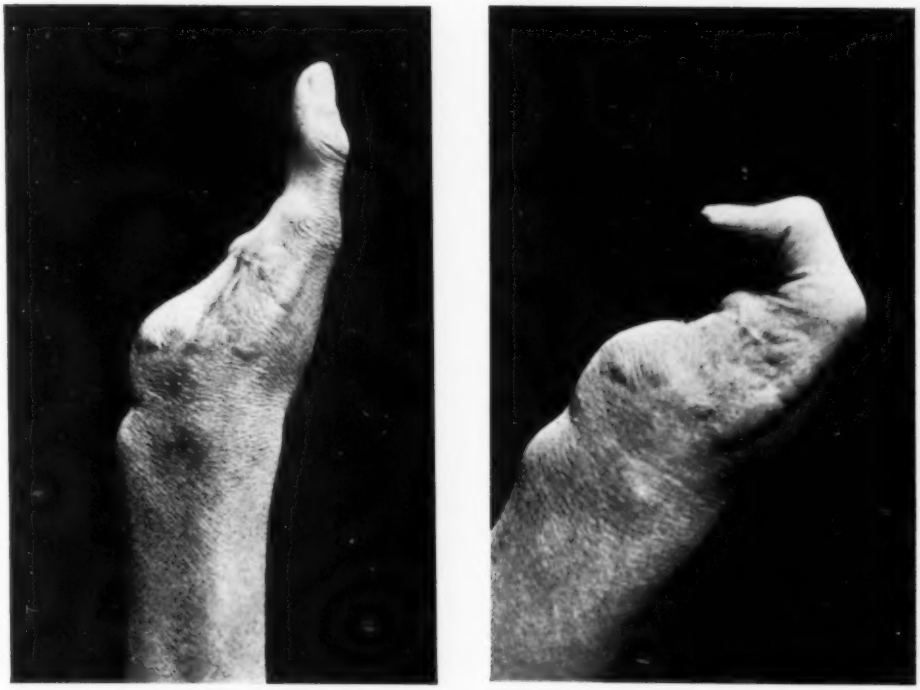

FIG. 1.—(Case I.) Stump of left hand before plastic operation, showing complete loss of the four fingers and adjoining metacarpus. The left photograph shows the only remaining digit, the thumb, fully extended. On the right, the thumb is shown fully flexed. Note the absence of any opposing surface for contact with the thumb, as a result of which nothing can be grasped. To restore function of hand, the construction of a new digit was undertaken by means of synthetic transplantation of tissues (see Fig. 2).

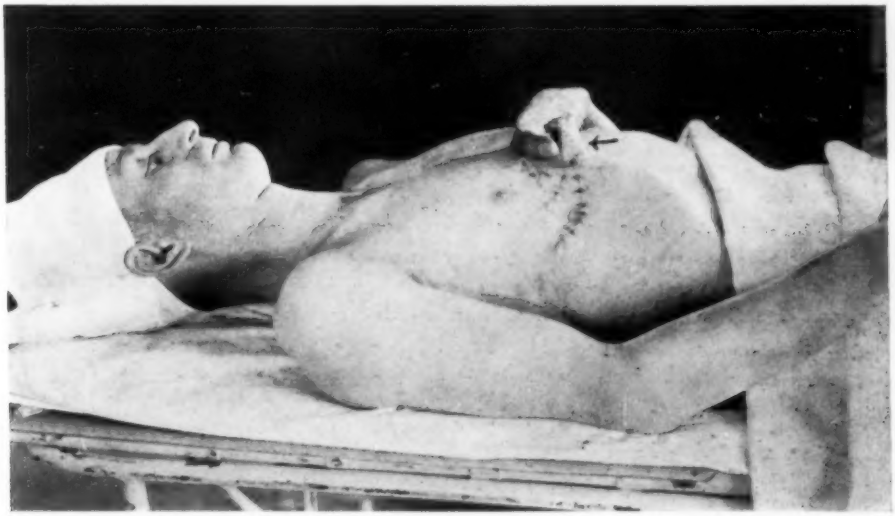

FIG. 2.—(Case I.) Showing first operative step in tissue transplantation. A rectangular flap of skin and subcutaneous tissue was turned up from the chest wall and sutured into the form of a finger. Its end was approximated to the edges of an incision in the stump of the hand made over and down to the distal surface of the os magnum, by the Italian plastic method. A pedicle (indicated by arrow) was left attached to the chest wall to supply nourishment to the newly implanted parts until circulation with the hand should be thoroughly established. (This photograph was taken at the time of removal of the plaster-of-Paris spica in which hand, arm and shoulder were incorporated for four weeks following first operation.)

FIG. 3.—(Case I.) Showing immobilization of hand and arm in plaster-of-Paris shoulder spica to prevent traction on the new boneless finger. Note that the thumb was left projecting for purpose of determining circulation of the limb. This case was removed four weeks after operation and the finger was then cut loose from the chest wall. The second operative step, consisting in the implantation of the bone graft, is illustrated in the radiogram, Fig. 4.

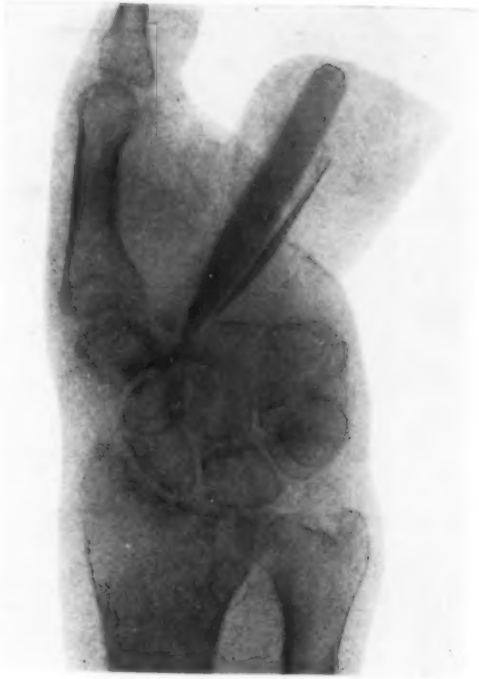

FIG. 4.—(Case I.) Röntgenogram of left hand with grafted finger, showing implantation of the two tibial bone grafts. In this operative step, the boneless finger, cut loose from the chest wall, was first tunneled by means of a scalpel and a wedge-shaped mortise was made in the distal-radial surface of the os magnum with an osteotome. Into this mortise a wedge-ended tibial graft, 3 inches long and about ⅓ inch wide, was firmly driven, in the position shown in this figure. A sliver graft (indicated in illustration) was affixed along the ulnar side of graft No. 1, for purposes of "bone-seed," or increased osteogenesis. The skin was closed with interrupted silk sutures.

This radiogram was taken four weeks after the transplantation of the tibial grafts which have now become firmly united to the bones of the hand.

Note the amount of bony extremity originally absent in the hand and the resulting loss of function, to restore which the synthetic transplantation of tissues was undertaken.

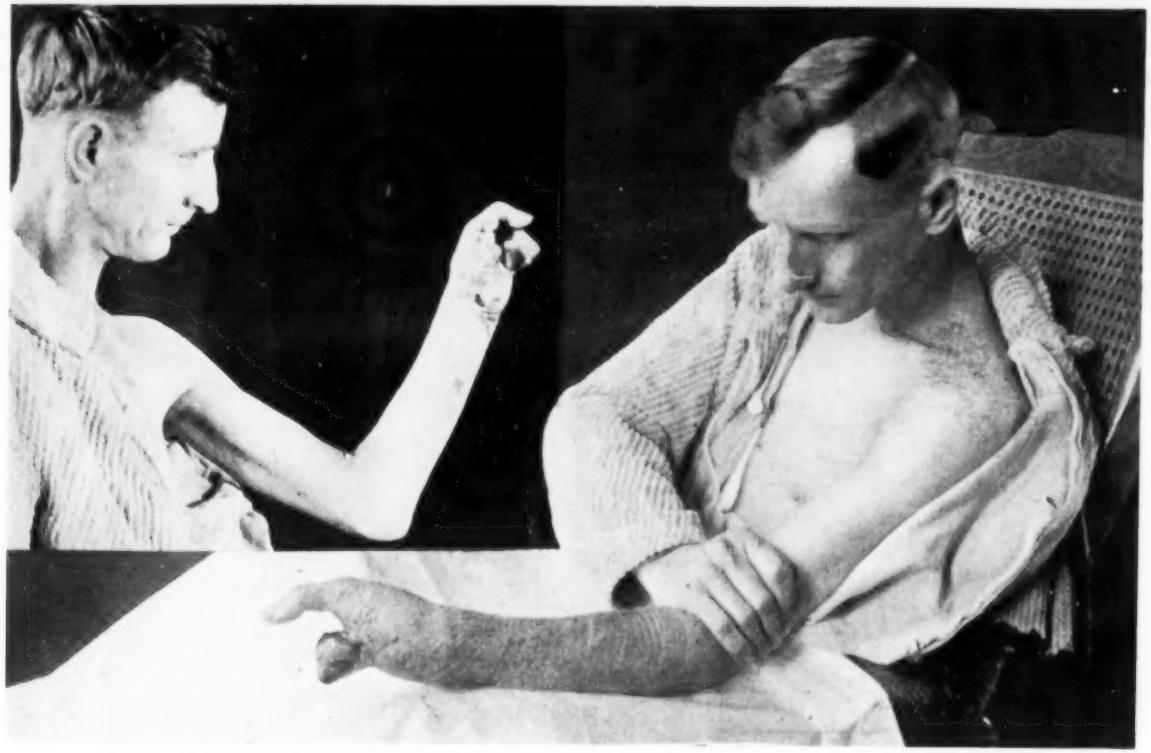

FIG. 5.—(Case I.) Showing the grafted finger four weeks after the last operation. The lower photograph shows the thumb fully extended. In the upper view the thumb is flexed and in apposition with the new finger.

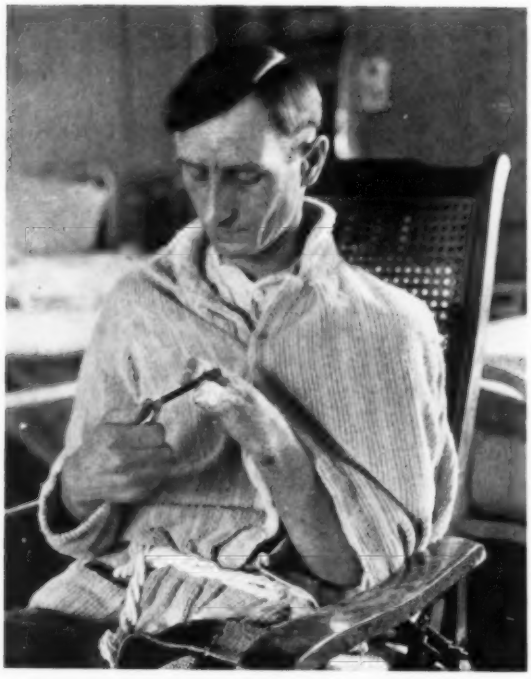

FIG. 6.—(Case I.) Showing new finger six weeks after the last operation. Note that the patient is now able to grasp and hold the pencil, which he is sharpening, between his thumb and grafted finger. By providing an opposing surface for contact with the thumb, the helpless stump shown in Fig. 1. has been converted into a useful member capable of performing most of the necessary functions of a hand, as is demonstrated in the photographs which follow.

FIG. 7.—(Case I.) The patient uses both hands in the natural manipulation of knife and fork.

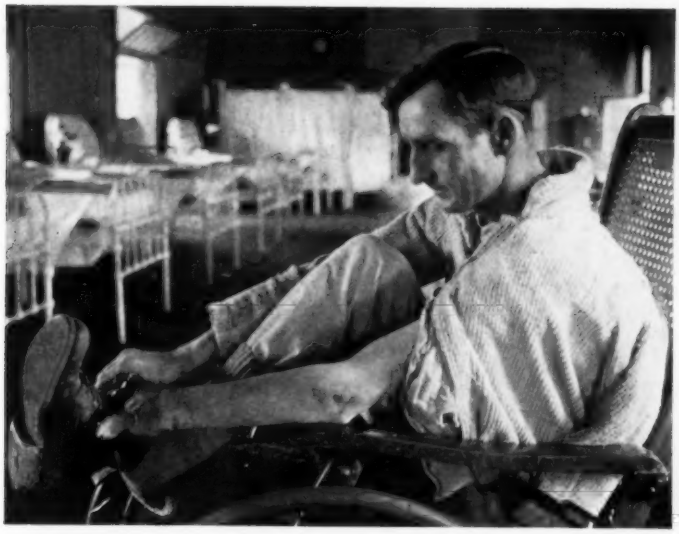

FIG. 8.—(Case I.) This photograph shows the coöperation of the two members in an act requiring strength and dexterity.

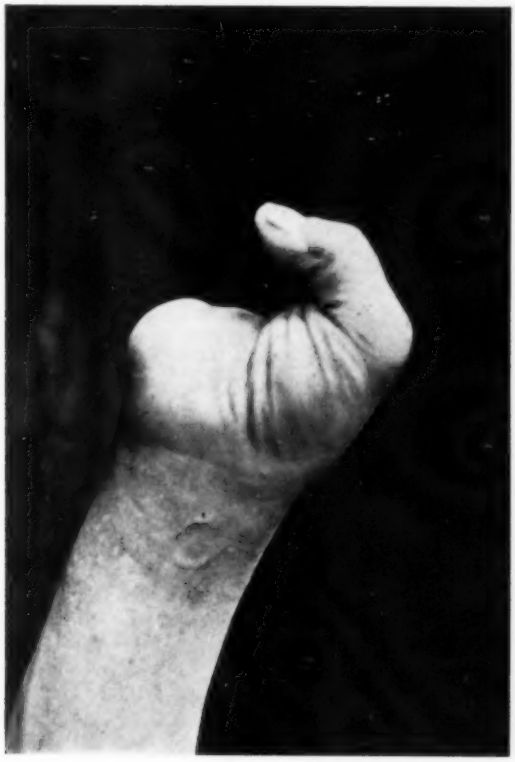

FIG. 9.—(Case II.) Showing stump of right hand, before plastic operation, with loss of the four fingers (and all but the proximal heads of the corresponding metacarpal bones). Note the gap between the stump surface and the thumb, when the latter is flexed as far as possible.

FIG. 10.—(Case II.) This photograph illustrates the method employed in this case of tissue transplantation, in which both bone and soft tissues were secured coincidently from the clavicle and overlying parts. By means of a pedicle left attached to the body wall, supply of blood was furnished until circulation with the hand was established in the new finger. (This photograph was taken after the removal of the plaster-of-Paris case in which the arm and hand were immobilized for four weeks following the operation.)

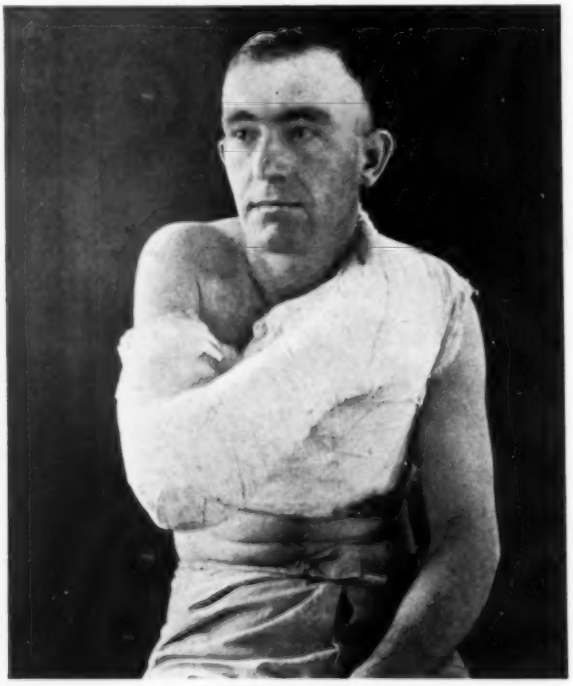

FIG. 11.—(Case II.) Showing immobilization of forearm and hand in plaster-of-Paris spica to prevent undue tension on the grafted finger. This case was removed four weeks after operation. The finger was then disengaged from the neck with an additional flap of skin which was later sutured so as to form the end of the new digit and to complete the covering of the bone graft which had become firmly united to the bones of the hand, as shown in the radiogram, Fig. 12.

FIG. 12.—(Case II.) Rontgenogram of right hand and grafted finger, taken eight weeks after the implantation of bone and soft parts, which are now united to the tissues of the hand.

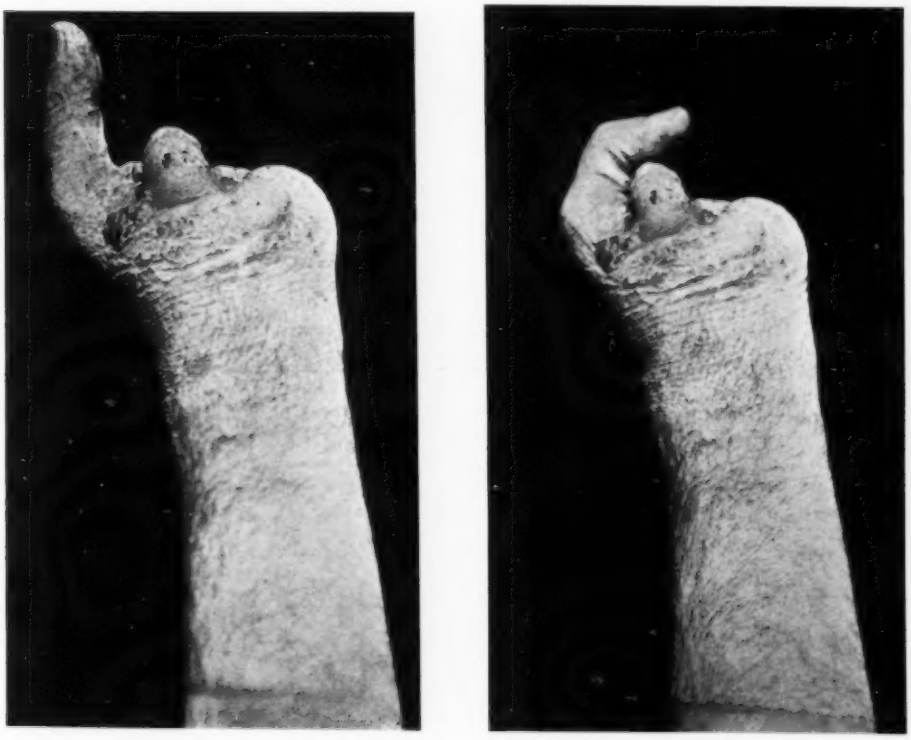

FIG. 13.—(Case II.) Showing the right hand with grafted finger, ten weeks after the implantation of soft parts and bone. On the left, the thumb is shown extended. The view on the right shows the thumb flexed and in apposition with the new finger.

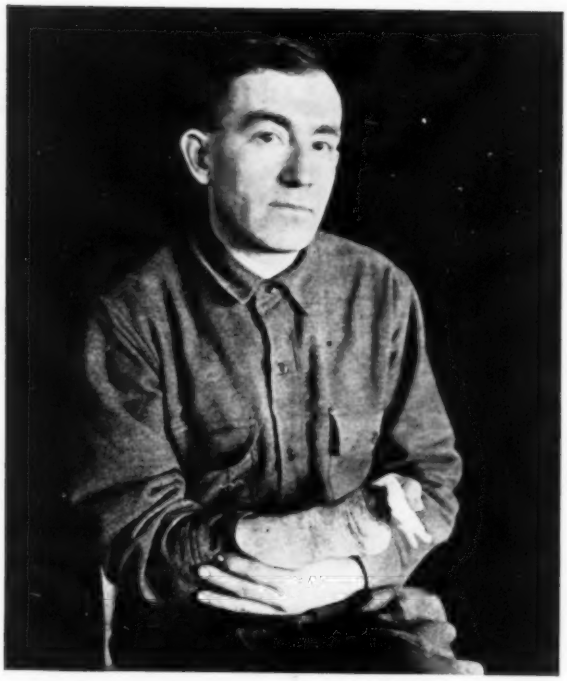

FIG. 14.—(Case II.) This photograph, taken at the same time as Fig. 13, shows the patient holding a sponge between his thumb and new finger.

form the end of the digit and to complete the covering of the graft which had become firmly united to the bones of the hand. In the radiogram, Fig. 12, taken four weeks after the removal of the plaster cast, the position of the tibial graft is demonstrated. Fig. 13 shows the right hand with grafted finger ten weeks after operation, at which time the patient was able to grasp and hold objects with his thumb and new finger, as shown in Fig. 14.

It is worthy of note in this case that at time of writing (March 21, 1919) sensation of touch has already progressed one-half inch in the new finger, showing that the nerve ends are actually regenerating in the grafted parts.

Discussion.—Of the two foregoing cases of tissue transplantation, the method employed in Case I is held to be the more satisfactory, not only in respect to technic, but because it affords greater freedom in choice of graft material and a more complete control of conditions favoring its growth. In this case, two independent operations were involved in the implantation of soft tissues and bone, respectively. Soft parts embodying the boneless finger were first transplanted from the thoracic wall and circulation with the hand was already well established in these tissues before the second operation, which consisted in the implantation of the bone graft from the tibia. In Case II, on the other hand, soft tissue and bone were taken coincidently from the clavicle and parts overlying, a procedure which involved the transplantation of two distinct graft tissues before the establishment of an adequate blood supply to the soft parts.

The utilization in Case I of the soft tissues of parts so accessible as the thoracic wall, or the abdomen, affords, in contrast to the foregoing method, a greater facility of technic. Moreover, the immobilization of the arm at a comfortable angle, permitted by this technic, is more conducive to normal circulation and to the ultimate establishment of blood supply in the newly grafted parts. This is an important preliminary step in the favorable sequence of bone transplantation. Into the tissues of the boneless finger, already well nourished, the transplants of bone were made in the second operative step, and their growth was thus assured.

Another advantage permitted by the method employed in Case I is the independent selection of graft tissue. Bone furnished, as in this case, by the tibia is nearly always preferable for grafting purposes, not only on account of its strength and its unusual osteogenetic activity, but also because this bone, by nature of its size and contour, offers a wide choice in the selection of graft material.

These cases emphasize the value and safety of extensive tissue grafting and demonstrate some of its possibilities in military plastic work.

NOTE.—Photographs by First Lieutenant A. J. Treichler, M.C., U. S. Army General Hospital No. 3, Colonia, N. J. Radiograms by First Lieutenant J. J. Sybenga, M.C., U. S. Army General Hospital No. 3, Colonia, N. J.

A NOTE ON EXPERIMENTAL CRANIOPLASTY

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The operative procedures advocated for the repair of bony defects in the vault of the cranium, though finding a somewhat limited field for application in civil life, have recently been the subject of much interest owing to the great incidence of head injuries in modern warfare. The purposes of cranioplasty are not only to replace the natural protective structures of the brain but also to restore, for cosmetic reasons, the shape and appearance of the head. In attaining these objects, the material used should be of such a character that the inner surface of the skull, both during and after repair, be maintained as free from irregularities as possible. The practical problems involved in this type of surgery have, in recent years, been met by a direct application of the osteoplastic procedures employed elsewhere in the body; fresh transplants of fascia, cartilage, long bone, and scapula have been repeatedly used for plastic work on the cranium. None of these tissues is entirely satisfactory, however, for neither the fascia nor the cartilage offer much more protection to the brain than the scalp and underlying connective tissues. Furthermore, the lack of density in cartilage and fascia gives these materials, when compared to bone, a limited usefulness as a supporting framework for the scalp in restoring the convexity of the head. The objection to the employment of bone obtained from other parts of the body is twofold. First, the source of supply, aside from the scapula, is almost entirely limited to long bones from which the transplants are obtained in strips. But a cranial defect, owing both to the convexity to be restored and the area usually involved, does not easily lend itself for repair with such material, for in order to conform to the curve of the head such transplants must be bent and to fill a large defect the grafts must be broken up and pieced together. A second objection to the use of this type of bone graft is that cartilage is produced during the process of healing. The ideal material for repairing cranial defects would consist of plates of the cranial bones themselves, for from these, pieces which would conform to the convexity of the part needing repair could be selected and, by properly beveling the edges, the inlay could be inserted in such a way as to afford immediate protection to the brain. In addition, the absence of cartilage formation in the healing of this variety of bone is of great practical value, in that bulky masses are not produced at the edges of the graft where union between the old and new bone takes place. The difficulty encountered in the employment of such material for graft purposes is the supply. Autogenous transplants of this kind, unless the defects are small, can hardly be considered, and heterogenous fresh grafts

are quite difficult to obtain. This inconvenience may be overcome, however, by keeping on hand a supply of sterilized pieces of cranium which could easily be obtained during routine autopsies.

To determine the relative values of dead and live cranial bone when used as transplants, experiments were carried out on cats. In the first of these, a simple transfer was made of trephine buttons removed from the heads of two animals. In one the transfer was made immediately but in the other the button was kept in warm Ringer's solution for thirty minutes before implantation. Healing was *per primam* in both instances. After a period of three months the animals were sacrificed. Examination showed that complete bony union had taken place around the entire circumference of each of the buttons, but, of more importance, the transition from old to new bone on the inner surface was perfectly smooth and free of any exostoses (Figs. 3 and 4). Coronal sections of the skull through the graft (Fig. 6) showed that while the centre of the transplant was thin, the tables at the edges of the transplant were separated by a well-vascularized diploë of normal thickness.

A third experiment was made to ascertain how the outer table of the cranium would serve for graft purposes. In this case a single animal was used. After exposing the skull beneath the temporal muscle on both sides, the cranium on the right was partially penetrated with a trephine and the outer table was removed with a chisel. In doing so, owing to technical difficulties, part of the inner table in a small segment of the button was removed also, leaving a defect through the entire thickness of the bone. This defect was not repaired. On the left side, a trephine button was removed in the usual way and into the opening so produced was inserted the piece of outer table previously obtained. The fit was not exact so that part of the defect was left uncovered. The temporal muscle was replaced over the bone fragment and held it in position. Healing progressed satisfactorily and after three months the animal was sacrificed. Examination of the skull showed that both of the uncovered defects left at the time of operation were still present in the original size. The piece of outer table had become fairly fixed at all points where it came in direct contact with the edge of the trephine opening and the inner surface overlying the dura was smooth and free of all irregularities.

The final experiments were made with dead bone. In the first of these a trephine button was removed from a dead cat which had previously been embalmed with 10 per cent. formalin. After removal, the bone fragment was boiled for ten minutes in water and then inserted into a trephine opening of corresponding size in the skull of a normal cat. The animal was sacrificed after four months. Examination of the skull showed that repair had taken place as satisfactorily as in the cases in which fresh bone was used, and that the inner surface of the cranium over the former defect was quite as smooth as the surrounding areas. An experiment similar to this was carried out with the transplantation of a button obtained from a dead, embalmed cat; in this case the bone was subjected to sterilization in the autoclave at fifteen pounds pressure for half an hour. The animal in which this graft was placed

was observed for three months, when it was killed. Healing in this instance was in all respects the same as already noted in the other animals (Figs. 1 and 2). Coronal section of the skull through the graft (Fig. 5) showed, as in the experiments with living bone, that the centre of the implanted bone was thin, whereas the outer edge was of normal thickness. The diploë at the periphery was well vascularized and corresponded in appearance to that of the adjacent old bone.

These experiments are essentially similar to those made on dogs by Barth [2] in his original investigation on the healing of bone grafts. Barth concluded, from analysis of his experimental evidence, that dead and living bone, when used for transplantation purposes, behaved alike during the process of repair and that either could be used equally well as graft material. His statements precipitated a lengthy controversy concerning the relative osteoplastic value of bone when employed under various conditions; this controversy resulted, mainly in consequence of the demonstrations of Axhausen,[1] in a partial reaction by Barth, who finally admitted the superiority of living bone grafts over dead. During this controversy, however, most of the experimentation had been done with the view of determining the procedures to follow in repairing defects of the long bones and in correcting deformities of the spine. The problems encountered in these fields, however, are quite different from those which arise in relation to the repair of cranial defects and the experience gained by investigating one problem cannot be directly applied to the other; in fact, Barth's deductions regarding the healing of bone have been adversely criticized because he endeavored to apply his generalizations derived from experiments on the flat bones of the head to the problems of osseous healing in other parts of the skeleton.

For repairing defects in the long bones where early strength and union are of primary importance, a graft not only should serve as a bridge between the broken ends of bones but also should take an active part in the process of repair. In osteoplasty of this nature the question of cartilage formation is of great importance, for not only does this tissue act as a very efficient splint, but its presence is indispensable to the process of repair. The production of a large bulky callus at the points of union, therefore, is a condition to be welcomed rather than avoided and the displacement of surrounding tissue under such circumstances is but a temporary inconvenience. If, after the cartilage has been absorbed, there persist, in the neighborhood of repair, bony nodules or even if exostoses project into the muscular tissue, such osseous growths rarely cause trouble, and if they do, their removal subsequently is not difficult. The best material for grafting purposes in the long bones has proved to be live periosteum-covered bone, for the reasons that (1) it can be obtained readily from other parts of the patient's own body; (2) it takes an active part in the process of repair in that it early becomes vascularized and aids in the production of callus and subsequently of new bone, and (3) grafts of such tissue "take" in a higher percentage of cases than any other material tried. For bridging a gap between the ends of a fracture, dead bone can be used, and under proper conditions, it is conceded, a union

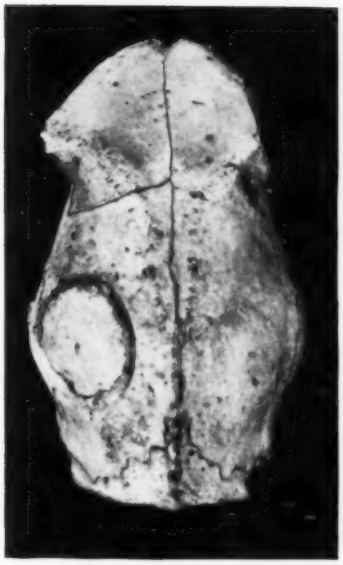

FIG. 1.—Exterior view of cat's skull into which there was implanted, three months previously, a sterilized button of bone. The button is shown in position. Bony union has taken place at the periphery and the button may be considered as a part of the cranium.

FIG. 2.—Interior view of same skull shown in Fig. 1. The implanted button, seen in the lower right hand corner, is hardly distinguishable from the surrounding bone. The transition from old to new bone is smooth.

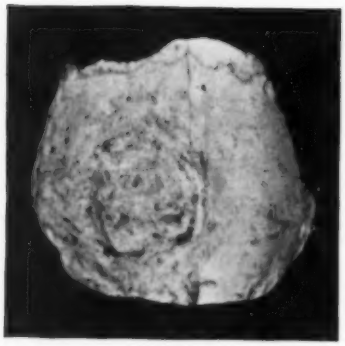

FIG. 3.—Exterior view of a cat's skull into which was implanted three months previously a button of bone which had just been removed from another normal cat. Healing has been complete and the original defect has been completely restored.

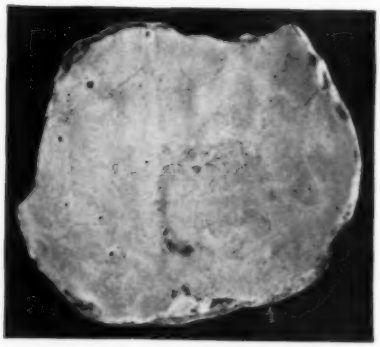

FIG. 4.—Interior view of same skull shown in Fig. 3. The smooth healing, apparent in Fig. 2, is likewise present in this case. In both instances the grafts are held equally firm by new bone.

FIG. 5.—Coronal section through graft shown in Figs. 1 and 2. The position of the graft is indicated by the white lines. Note the thickness of the diploë at the periphery of the transplants and the even contour of the inner table of the skull over the points of union between graft and old bone.

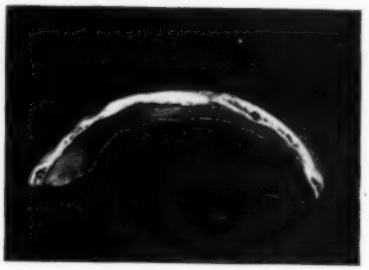

FIG. 6.—Coronal section through graft shown in Figs. 3 and 4. The white lines indicate the position of the graft. The diploë at the periphery of the graft is of normal thickness and the contour of the inner table, as in Fig. 5, is even and smooth over the healed area of skull.

will be formed between it and the bone to be repaired. But dead bone plays no active part in repair and when such material is used the chances of a "take" are somewhat less than they are with fresh tissue.

In the repair of cranial defects, a protective bridge is the essential requirement and the immediate need for a strong union is not so great as it is in other parts of the skeleton. By using a properly selected plate of cranial bones, a protection for the brain may be effectively obtained even before repair has advanced, provided only that the graft be properly beveled and inserted in such a way that pressure from without is transmitted to the edge of the defect. In this location, where the bones are immovable and muscular pull is hardly to be reckoned with, permanent fixation of grafts can be obtained by the use of pegs or similar appliances at the time of operation so that the formation of a cartilaginous splint to hold the fragments is not necessary. Neither is the presence of callus needed in the process of subsequent repair, for union between fractured bones of the cranium takes place directly between the opposing surfaces of the fragments in much the same manner that *per primam* healing proceeds after laceration of the integument. On the other hand, the formation of callus, which follows the use of living bone obtained from other parts of the body, is to be avoided, for the encroachment, even though temporary, by a mass of such material into the cranial cavity may do harm. Furthermore, as is well known, after the absorption of callus has been effected, there may be left osseous excrescences capable of causing in the central nervous system local irritations difficult to remedy. Live cranial bone may have an advantage in cranioplasty over dead bone in that the living tissue may be vascularized and replaced more quickly. But this time element is not as important in the skull as it is elsewhere, for so long as the requirements of protection to the brain and restoration of the shape of the head are fulfilled, replacements of the graft with new osseous tissue may proceed either quickly or slowly. This slight advantage on the part of living cranial bone, however, should be recognized in the selection of material and live grafts should be used when possible, but unfortunately, the opportunities for obtaining such tissues are few. The experiments on cats reported here indicate that well sterilized dead cranial bone forms a good substitute for the living, and, for the reasons given above, it should be used in preference to bone grafts obtained, even though fresh, from other parts of the body. It would hardly be justifiable though to conclude from these experiments on cats that the same procedures would be applicable to man, for in these small experimental animals the pieces of bone used were not analogous to those necessary for the repair of the human cranium. The reaction of a cat's tissue to a small piece of dead bone the size of a trephine button (2.5 cm.) may not be noticeable, whereas in man the larger bulk of foreign material represented by a plate of sterilized bone may possibly cause an entirely different reaction. Sicard,[3] however, has reported recently a series of eighty-five human cases in which cranioplasty was performed with plates of bone taken from the skulls of cadavers and he states that such plates of thoroughly sterilized bone are well tolerated by the tissues.

CONCLUSIONS

The problems of cranioplasty cannot be met entirely by the experience obtained from osteoplastic work on the long bones. The logical material to use in cranioplasty consists of plates of cranial bone, for (1) the requirements of protection for the brain and restoration of the shape of the head can be immediately accomplished; (2) the formation of cartilage, with possible resulting exostoses, is avoided. Animal experimentation (on cats) indicates that either living or dead grafts may be used effectively in the head. In man, living grafts are recommended, but if they are not available, plates of sterilized cranial bone are preferred to any other tissue.

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HYPERTONIC GUM ACACIA AND GLUCOSE IN THE TREATMENT OF SECONDARY TRAUMATIC SHOCK

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At the time this country was drawn into the world war the Committee on Physiology of the National Research Council decided to interest our physiologists in a coöperative investigation of surgical shock. Since then this laboratory has devoted all of its facilities and all of its research time to the study of that problem. One line of our experiments led us to the use of a strong solution of gum acacia and glucose in water in the treatment of shock. It is the purpose of the present paper to review briefly the experiments that led us up to that point,* and to present in detail the results, still quite limited, that have been obtained through the use of the solution in the treatment of shock and allied states in man.†

REVIEW OF EXPERIMENTS ON THE MECHANISM OF SHOCK

The first experiments done here were planned with the idea of familiarizing ourselves with the state that has been called shock by those who have worked on the subject, and of determining which manifestations of the state are fundamental to its development. These objects we hoped to attain by studying shock as produced in diverse ways. For, if it could be demonstrated that certain disturbances were constantly present there would be presumptive evidence that they were essential to the state of shock, and we would then be provided with a basis for the development of rational methods of treatment.

We believe we have succeeded in producing in the anæsthetized dog a condition resembling so-called secondary shock (*a*) by the usual method of exposing and manipulating the intestines;[1] also (*b*) by so occluding the inferior vena cava, between the diaphragm and the liver, as to hold the arterial pressure down to about 40 mm. Hg. for a period of about two hours;[2, 3] (*c*) by occluding the thoracic aorta, distal to the origin of the left subclavian artery, so as to keep the arterial pressure beyond down to

* This phase of the work was begun in collaboration with my associates, Robert Gessell and Herbert S. Gasser, and was carried to completion by the latter and the author. Formal reports were submitted to the Committee as the work progressed and preliminary reports have been made before the Washington University Medical Society. It is being prepared for publication in full in the American Journal of Physiology.

† The results have been reported to the Committee and before the Washington University Medical Society. Doctor Gasser was prevented by war exigencies from participating in some of the preliminary experiments and in the clinical studies.

20–40 mm. Hg for a period of about two hours,[3] and (*d*) by the continuous intravenous administration of adrenalin at such a rate as to maintain a high arterial pressure for a period of twenty or more minutes.[4, 8] The symptoms eventually exhibited by animals exposed to these four forms of treatment are very similar; in all there is a characteristic apathy, usually with persistent eye reflexes, an inefficient circulation, as evidenced, when the condition is fully developed, by a low arterial pressure, a reduction in blood volume accompanied by concentration of the blood, and a reduction in reserve alkalinity. Furthermore, the pathological pictures, in certain respects, also are alike in all.

THE CIRCULATION IN SHOCK

In an effort to ascertain the *cause of failure of the circulation,* a study was made of (*a*) the arterial pressure, of the venous pressure, both (*b*) jugular (right auricular) and (*c*) portal, and of (*d*) the peripheral resistance.

A. Arterial Pressure.—The usual criterion of shock is a low arterial pressure. In the absence of this sign most laboratory workers, and perhaps clinicians, also, would not feel justified in making the diagnosis of shock. Yet, in agreement with Gesell[5], we are of the opinion that, in animals, at least, the circulation may be markedly reduced before the arterial pressure begins to fall. Thus in experiments on caval shock, after de-occluding the inferior vena cava the arterial pressure rises for a time to mount as high as, often higher than, the normal initial level. Observations on over 200 instances of this kind of shock have shown that if the arterial pressure begins to fall consistently before two hours have elapsed after decompressing the cava, the fall continues (there has been but one exception) until the circulation completely fails. If, in such instances, the animal is not in shock at the time its arterial pressure is still high, it at least seems justifiable to assert that shock is then developing. One of our cases of shock in man, as will be seen, possibly belongs to this category.

B. The *jugular pressure* is supposed to be an index of the effectiveness with which the heart pumps on the blood that is returned to it. We have been impressed, however, by the uncertainty of this method of judging the efficiency of the heart. However this may be, it can be asserted that in none of the types of shock we have studied has there been any material increase in jugular pressure, and yet we are convinced that in shock the heart may not preserve its normal efficiency. While it is true that against the extreme constriction produced by a large dose of adrenalin, or against a closed aorta, the heart in shock often is capable of raising the arterial pressure quite as high as can the heart of normal animals,[6] yet we have obtained evidence indicating that the shocked heart may be incapable of such sustained efforts as is the normal heart.

C. The *portal venous pressure* during shock induction is elevated by some of the procedures (markedly by adrenalin, slightly and temporarily by caval occlusion), and lowered by other procedures (intestinal exposure

and aortic occlusion). Therefore, increased filtration of blood from the splanchnic and portal areas, or sequestration of blood in these areas by mechanical distention of the veins and capillaries[2] through local constriction of the portal radicles [7, 8] cannot be regarded as essential to the development of shock. It is, however, possible to bring on shock by mechanically interfering with the outflow of blood from the portal area. Thus shock develops after plugging the smaller radicles of the portal vein in the liver by injecting into the portal vein a suspension of lycopodium spores.[3] But unless the obstruction so produced is much more complete than any that could possibly develop through any known physiological mechanism, the time required for the onset of shock greatly exceeds that elapsing during the induction of the types of shock that are seen in the laboratory.

D. The *peripheral resistance,* as followed by a modification of a method first used by Bartlett in this laboratory, also in a study of shock,[9] does not behave similarly during the induction of shock by the different procedures. Thus, as a result of exposure of the intestines, the peripheral resistance in both the somatic and splanchnic areas at first usually is increased; later, and usually only after the arterial pressure has started downwards, dilatation occurs. During caval occlusion the peripheral resistance is first increased, but soon becomes subnormal. During aortic occlusion the resistance is decreased, but it increases after de-occlusion, and usually remains high practically until the animal dies. Finally, those doses of adrenalin that bring on shock produce, through local action, an extreme and long-lasting peripheral constriction.

These observations clearly indicate that the condition in which the vasomotor centre finds itself in fully developed shock, namely, whether hyperactive or hypoactive, depends very largely upon the procedure employed for the purpose of inducing shock. Neither reduced nor enhanced vasomotor activity is an essential condition of shock. But in any event, the center is apt to become hypoactive after the circulation has been deficient for some time.

Analysis of the data derived from this study of the circulation in shock, while indicating that the low arterial pressure in advanced shock may in part be due to some inefficiency of the heart, and sometimes, also, to some decrease in the activity of the vasomotor centre (though increased tone is more common), clearly demonstrates that these two deficiencies, even when present, are not in themselves sufficient to account for the failure of the circulation. If, then, the efficiency of the heart is but little reduced, and if increased vasomotor tone is the rule, there is left as the only other possible explanation of the low blood-pressure of shock an insufficient return of blood to the heart.

Blood-Volume.—In an effort to ascertain whether there is a deficient blood supply, a study was made of the blood-volume in animals in shock.[10] For this purpose the method of Meek and Gasser [11] was employed. This method consists in allowing a known amount of gum acacia to circulate in the blood stream for a period of ten minutes and then in determining the per cent. of gum in the blood. The method, therefore, determines the amount

of blood participating in the circulation in the course of ten minutes. The blood-volume changes were followed also by counting the red corpuscles and by estimating the per cent. of hæmoglobin. The latter two methods have shown that depletion of the blood plasma occurs in all types of shock, indicating a reduction in blood-volume averaging 20.3 per cent. But the acacia method of determining the blood-volume brings out the fact that the loss in volume by this concentration of the blood (disappearance of plasma) in many instances does not account for the total reduction in blood-volume. The blood unaccounted for by concentration must therefore be out of circulation; it must be stagnant somewhere.

These results confirm the well-known fact [12] that but little blood can be obtained by bleeding an animal in shock. The following experience is cited by way of illustration of what is meant: An animal weighing 15 kilo was put into shock. At a time when it still had a fair arterial pressure, 70 mm. Hg, as much blood was drawn from the carotid artery as it was possible to obtain by the use of all of the devices for obtaining a maximum yield. Only 100 c.c., or one-twelfth of the estimated normal volume, were obtained, whereas at least three-fifths could easily have been obtained from a normal animal. It follows from such observations that the volume of blood that is in the body of a shocked animal and which is thoroughly mixed in the course of ten minutes is very much larger than the quantity that effectively participates in the circulation.

In this connection attention should be called to an observation indicating that the animal in shock attempts to combat the reduction in blood-volume by adding tissue fluids to the blood. Refractometer estimations have shown that even while plasma is disappearing from the blood stream, its protein content may be diminishing [13]; that is to say, the plasma is becoming more dilute. It would, therefore, seem that all parts of the vascular bed are not affected alike during the induction of shock; in some parts the normal reaction to decreased volume, namely, the passage of fluids from the tissues to the blood stream, is possible, whereas in other parts the alterations are such as to allow of outward transudation only. Our observations furnish some reasons for believing that the ability of the organism to thus make good the loss in blood plasma diminishes as shock deepens.

Reserve Alkalinity.—The reserve alkalinity, as indicated by the CO_2 in the plasma of arterial blood (Van Slyke method), is reduced in all types of shock; but in our experience the reduction is extremely variable.[3] The volume per cent. of CO_2 may be below 20, that is, extremely low, or it may not be below a figure often obtained in estimations made before starting to induce shock. We have seen heavily morphinized animals with 20 volume per cent. of CO_2 and an arterial pressure of 103 mm. Hg., only 3 mm. below the initial arterial pressure. Therefore, acidosis, though probably always present to some degree, can scarcely be regarded as a cause of the low arterial pressure of shock, as some have believed [14], or even as an essential feature of the shock complex.[15]

PATHOLOGY.—At autopsy, which in our hands, unfortunately, has never been as thorough as pathologists might desire, the organs of the animals dead of all of the types of shock we have studied, present a very similar picture.[3] The intestines are apt to contain some bloody material; and the mucosa, especially of the upper end of the jejunum, usually is deeply injected and of a bluish-red color. The spleen may be uniformly or unevenly enlarged and may contain hemorrhages. The liver usually is not enlarged and may contain less than the normal quantity of blood. Rarely the gastric mucosa shows hemorrhagic areas. The most remarkable feature, though, is brought to light by microscopic examination of the intestines: *in all types of shock the capillaries and venules of the villi are tremendously distended* by solid masses of red corpuscles.

THEORETICAL.—If, now, we pause to consider the methods by which we have succeeded in producing shock, we are struck by the fact that at least three of the four, namely, caval occlusion, aortic occlusion, and massive doses of adrenalin, involve reducing for some time the rate of movement of the blood through a considerable portion of the body; and if we accept the prevailing view that the blood stream eventually is slowed in regions that are the seat of an inflammatory process, it is to be presumed that as a result of intestinal exposure also, the blood stream in the splanchnic area is slowed. Furthermore our experiments, showing that, as a rule, traumatizing the abdominal viscera results in a certain amount of general constriction, and Gesell's observation[5] that the volume flow of blood through the salivary gland under similar circumstances is markedly reduced, indicate that during the development of this type of shock, also, the blood stream is slowed throughout the whole of the body.

Mall and Welch have followed under the microscope the changes in the flow of blood occurring in the smaller mesenteric vessels of the dog when the rate of blood-flow through them is slowed by partial obstruction of the mesenteric artery. In his classical article on Embolism and Thrombosis, Welch[16] describes these changes about as follows: The smaller and then the larger (microscopic) veins become more and more distended with red corpuscles and all of the phenomena of an intense venous hyperæmia appear. The red corpuscles accumulate in clumps or in solid columns. *This change may become permanent, producing an evident obstacle to the forward movement of the blood.* The same phenomena of distention with red corpuscles, clumping, and stasis appear gradually in the capillaries. With this partial blocking of the veins and capillaries the corpuscles begin to pass through the wall of the vessels by diapedesis.

Although Mall and Welch seem inclined to attribute this clumping of corpuscles to the absence of pulsation, their evidence does not preclude mere slowing of the blood-stream as the cause of the phenomenon. Assuming that slowing is the cause, we have in the peripheral mechanism thus started by a slowing of the blood-stream a means of accounting for all of the characteris-

tic changes in the circulation that occur in experimental shock. The concentration of the blood and the reduction in blood-volume are explained by the transudation of plasma which must precede the diapedesis observable under the microscope. The failure to obtain by bleeding, as much blood as the blood-volume methods indicate is present in the body is accounted for by the dilatation and plugging of the capillaries and venules. Reduction in reserve alkali is known to accompany deficient oxygenation of the tissues. While the low blood-pressure, naturally, is to be referred to the reduction in effective blood-volume due in part to the actual reduction by transudation and in part to the stasis in the capillaries and venules.

II. Review of Experiments on Treatment

Preliminary Experiments.—While making estimations of the blood-volume in shock by the acacia method it was observed [10] that the concentration of the blood that ordinarily occurs during the development of shock, did not occur, or, at least, was not nearly as marked as usual, in animals that had received a preliminary dose of 20 per cent. gum acacia. This observation forms the basis of our experiments on the treatment of shock. An investigation of this action of strong gum acacia led us [18] to conclude that in all probability it is referable in part, at least, to the osmotic pressure it exerts, and possibly in part to other properties.

By following the changes in hæmoglobin content of the blood it was found that when 25 or 30 per cent. gum acacia is quickly injected into the circulation the blood dilutes slowly, the maximum dilution being attained in from 25–30 minutes, the subsequent return to the normal concentration requiring many hours. This reaction to the injection of a hypertonic solution of the colloid gum is very different from that given by the injection of hypertonic crystalloid solutions. Thus a hypertonic (18 per cent.) glucose solution injected into the same animal some days subsequently led to a similar dilution of the blood; but in this case the maximum dilution was attained practically instantaneously, and within five minutes practically all of the water that had been drawn into the circulation by the glucose, had again returned to the tissues. By first injecting a strong gum solution and following it immediately with the strong glucose solution we found it possible, both in normal and in shocked animals, to expand the blood-volume as rapidly as injected crystalloids (glucose) are known to attract water into the blood-stream, and to maintain that expansion as long as colloids (gum acacia) are known to maintain dilution of the blood.

A series of experiments on animals in shock was then performed in order to ascertain whether the course of shock could be influenced by the administration of gum alone or of gum in combination with crystalloids. It was found that such solutions as simple isotonic [17] * (7 per cent.) gum acacia, 6 per cent. gum acacia in 2 per cent. $NaHCO_3$, 25 per cent. (hypertonic) gum acacia (sodium salt) and 5 per cent. (hypertonic) $NaHCO_3$ given in succession, and 25 per cent. (hypertonic) gum acacia and 18 per cent. (hypertonic)

* Recent estimations indicate [10] that 7 per cent. gum acacia is hypertonic.

glucose, also given in succession, all restore and maintain with equal effectiveness the blood-volume and the blood-pressure, while the bicarbonate solutions (at least the stronger of the two) restore the alkali reserve also. The ultimate result, however, that is, whether or not the animal recovered from shock, did not seem to be influenced by thus successfully treating these symptoms of shock. It followed that the efficacy of any proposed treatment of shock cannot be judged, or at least not solely, by the effect it may have upon these manifestations of shock during the limited period of observation of an experiment as ordinarily performed. An empirical study of the ultimate effects of administering these and similar solutions to animals after standard traumatization seemed, therefore, to be the only way of obtaining the desired information.

Experiments on the Treatment of Standardized Traumatization.—The ideal test would have been to have inflicted that amount of damage from the effects of which animals could just not recover; that is to say, the minimal fatal dose of damage, and to have determined whether treatment of animals so prepared saved life. It was found, however, that when this amount of damage was done the animals invariably died, irrespective of the treatment administered. After many trials we [3] adopted, as the standard damage, so clamping the inferior vena cava as to hold the arterial pressure at 40 mm. Hg for two and a quarter hours. It was found that if the arterial pressure did not fall within two hours after removing the clamp, animals so treated stood a 52 per cent. chance of recovering. It might be added that if the arterial pressure began to fall consistently before two hours had elapsed, again, no form of treatment whatever prevented a fatal issue. It is needless to state that aseptic precautions were carefully observed.

Large numbers of animals, after exposure to this measured traumatization, were treated with (*a*) 6 per cent. gum acacia in 2 per cent. $NaHCO_3$, 12 c.c. per kilo of body weight; (*b*) 25 per cent. gum (sodium salt) followed by 5 per cent. $NaHCO_3$, of each 5 c.c. per kilo; (*c*) 25 per cent. gum followed by 18 per cent. glucose, of each 5 c.c. per kilo, or (*d*) 25 per cent. gum in 18 per cent. glucose, 5 c.c. per kilo.

Our reasons for trying just these therapeutic measures were as follows:

Solution *a* we took as representative of a solution of gum and of a salt practically isotonic with the blood (though to be sure it was alkaline also). An additional reason for using it was that it was then the solution recommended by the English committee [17] for the treatment of shock at the front. More recently the English committee have given their support to a solution consisting of 6 per cent. gum acacia in 0.9 per cent. NaCl.[18] The efficacy of this solution we have not had the opportunity to test.

Treatment *b* was used mainly for the purpose of determining the effect of a hypertonic salt, which at the same time was strongly alkaline, in combination with hypertonic gum. It served to test not only the effect of restoring the blood-volume by osmotic action, but also the efficacy of alkalies, which were then being employed in the treatment of shock [19] and which have from

time to time been advocated for that purpose on the basis of their effect upon the blood-pressure [20, 21, 22, 23] and on the basis of theoretical considerations.[5] In order to obtain the desired osmotic effect the bicarbonate, as used by us, was in slightly greater concentration than it was being employed in man; but the dose per unit of body weight was less and the rate of administration was slower. The fact that the alkali was used in combination with gum acacia complicates somewhat the inferences our results seem to justify, though gum acacia in other combinations has not proved harmful.

Treatment *c* involved the use of hypertonic glucose, which experiments with Woodyatt [24] had let us to believe acts beneficially in shock. It has been shown by Woodyatt and co-workers [25] and more recently by Litchfield [26] that man, even when desperately ill, is not injured, indeed is benefited, by extraordinarily large doses of hypertonic glucose solution given at a subtolerant rate. Furthermore, hypertonic solutions in general (urea, glucose, NaCl) increase the cardiac output and dilate the arterioles, apparently through some specific action.[27] These, and other responses to be referred to later, are exactly the ones best calculated to counteract the mechanism which we believe is at the basis of the vascular failure of shock.

Treatment *d* was used for the same reasons and also for the reason that by it the deleterious effects of the high viscosity of the strong gum solution, which are operative for a time during the injection of the gum in treatments *b* and *c*, are completely obviated by the immediate dilution of the gum by the water attracted from the tissues by the hypertonic glucose. Solution *d* was so given (5 c.c. per kilo an hour) that the glucose entered the circulation at a rate that is just subtolerant for the normal animal.[25]

TABLE I

RESULTS OF TREATING MEASURED TRAUMA

Treatment	No. of animals	Deaths		
		Total, per cent.	After excl. abd. hem., per cent.	After excl. cardiac cases, per cent.
Controls	23	48	37	45
(*a*) 6 per cent. gum in 2 per cent. bicarbonate, 12 c.c. per K	20	45	35	42
(*b*) 25 per cent. gum and 5 per cent. bicarbonate, 5 c.c. of each per K	16	56	50	53
(*c*) 25 per cent. gum and 18 per cent. glucose; 5 c.c. of each per K	20	45	31–35	39
(*d*) 25 per cent. gum in 18 per cent. glucose; 5 c.c. per K. hr.	21	24	6–11	20

The essential results that came of this study are collected in Table I. This table shows, 1, that treatment *b* unquestionably is harmful; 2, that treatment *d* unquestionably is beneficial; and 3, that while treatments *a* and *c* seem to accomplish some good, the variations from the results of the control series are so slight that they unquestionably fall within the limit of the experimental

error. It should be added that the harmful effects of treatment *b* were also clearly manifested by the shorter span of life of the fatal cases.

No ill effects of giving gum acacia have been seen except early in our work when the strong gum solution was run very rapidly into the vein of an animal almost moribund. In several instances of this kind the heart became irregular and stopped as though it had passed into fibrillation. Since then we have given the gum solution to at least 200 animals, including those collected in Table I, animals so seriously injured that their lives actually were in the balance, and not a single bad effect has been observed. If there is any one thing we are convinced of, it is that gum acacia when given slowly is entirely innocuous.

Hemorrhage Does Not Contra-indicate the Use of Hypertonic Solutions.—Shock in man often, in war surgery perhaps always, is complicated by hemorrhage. The use of the strong gum-glucose solution in the treatment of cases complicated by dangerous hemorrhage would therefore not be justifiable unless it could first be shown in animals that such a hemorrhage is not a contra-indication to its administration. The results of a series of experiments planned for the purpose of testing this matter have been to show[3] that even when the corpuscles are reduced to an extremely low level by a hemorrhage that ordinarily proves fatal, the gum-glucose solution accomplishes a certain amount of good; deleterious effects were never observed.

III. Observations on the Use of the Hypertonic Gum-Glucose Solution in Man

Methods.—Preparation of the Solution.—The gum-glucose solution that was employed in most of the animal experiments described above and in the treatment of the cases of shock and allied states, to be described below, was made up as follows:

Two hundred and fifty grams gum acacia, "extra select," in pearl form (gum arabic, U.S.P.) are ground up and dissolved in 720 c.c. hot water, freshly distilled from glass. Constant stirring is necessary to prevent gumming of the acacia into a very slowly dissolving mass. To this solution 180 gm. pure glucose are added. The whole will amount to about 1000 c.c. The solution is filtered under pressure through a thick pad of glass wool, heated in an autoclave to a temperature of 120° C. for a few minutes, preferably in a sealed, high pressure, flask and then filtered under pressure through an alundum filter dish of a porosity of R. A. 98.

The filtered solution is then filled into tubes of the shape shown in Fig. 1, made to fit the cup of our largest (100 c.c.) centrifuge. Larger tubes, holding about 350 c.c. would be preferable, for then the maximum dose for man would be in one container; but we have been unable to obtain the use of a centrifuge of sufficient capacity to take larger tubes. In order to avoid the formation of bubbles, which, in such a viscid solution, are apt to persist for some time, the solution should be made to run down the side of the tube.

The tube, when filled, is sealed hermetically at *A*, and sterilized by heating to 120° C. in an autoclave for fifteen minutes (no longer).* A slight flocculent precipitate is apt to form during sterilization. This is thrown down firmly against the bottom of the tube by centrifuging the material for about an hour.

Administration.—The ampoule is opened by filing a scratch and breaking

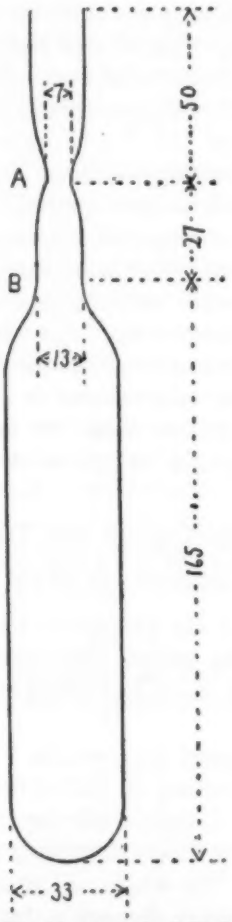

FIG. 1.—Ampoule. Reduced to ⅓ natural size. The dimensions are given in mm.

at *B* (Fig. 1). The opening thus made is flamed and the contents of the tube are so decanted as not to stir up the sediment. The sediment is usually firmly fixed to the bottom of the tube, but in order to avoid the danger of pouring it off, the last few cubic centimetres should not be decanted.

* In order to avoid the change that occurs in both glucose and gum acacia solutions as indicated by a slight deepening of color when they are sterilized under pressure, we at first sterilized them by pasteurization. Our experiments have shown, however, that the solution, even after several heatings to 120° C., is quite as efficacious and quite as innocuous as the pasteurized material. We, therefore, have come to employ the autoclaved solution only.

For the slow and steady intravenous administration of such a viscid solution special apparatus is needed. The apparatus devised by Woodyatt [25] probably would answer every requirement, but it is expensive and can be used only where electricity is available. We have designed for the purpose a burette with a capacity of 350 c.c. and a bore of 35 mm., calibrated upwards from the stem in small divisions (5 c.c.). Owing to the high viscosity of the fluid, its rate of inflow can be nicely controlled simply by varying the elevation of the burette; while the calibration of the burette from the stem upwards, makes it possible to utilize the last drop of the material. In order to avoid trapping air bubbles in the solution during the transfer, it should be made to run down the side of the burette.

Again owing to the high viscosity of the gum-glucose mixture, the injection needle must have an unusually large bore. It need not, though, be quite as large as the needles that have been recommended for use in the transfusion of blood.[28] The needle we have used (Fig. 2) is of silver, with inside and outside diameters at least at the point of 1.5 and 1.8 mm. respectively. Ordinarily it is not at all difficult, if it is properly pointed and sharpened, to insert a needle of this size into the vein through the skin. The author has convinced himself of this through use of the needle in a large series of cases

FIG. 2.—Injection needle. Natural size.

for the purpose of drawing blood samples for the Wassermann test. If, in any case, difficulty is anticipated on account of the smallness of the veins, the vein should first be exposed. After the burette and tube have been filled with the solution to the total exclusion of air, the needle is inserted into the vein, allowed to fill with blood without permitting of any loss, when the tube is rapidly slipped over the end of the needle which is so shaped as to facilitate this step. It is needless to add that all of the apparatus must be carefully sterilized and that the usual aseptic precautions must be observed.

The dose we used in the animal experiments was 5 c.c. of the solution for each kilo of body weight, and in order not to exceed the tolerant rate of glucose administration (0.8–0.9 gm. per kilo and hour), this dose was given in one hour. This particular dose was selected because it was found by experiment to be about the amount necessary to restore to normal the blood-volume of shocked animals. As no ill effects were produced by twice this dose administered at twice this rate, it may be regarded as a perfectly safe one for man. Experience has confirmed this conclusion. We have never repeated the dose, mainly, as will be seen, because we have not had the opportunity in instances in which a second dose was indicated. We feel convinced, though, that it would be perfectly safe to give, say, one-half the maximum dose some 8 to 10 hours after a maximum dose has been given.

Criteria of Effects.—The animal experiments made it clear that the immediate effect upon certain of the manifestations of shock, namely, the blood-

pressure, the blood-volume, and the reserve alkalinity, is of no value as an index to the ultimate efficacy of any treatment of shock. It was on this account that our conclusions were based solely upon the number of animals surviving a measured amount of damage. Complete recovery from the state of shock must be and is our final criterion of the efficacy of treatment of shock in man also. But while it is true that the state of these signs at any given moment is no sure index to the ultimate outcome, nevertheless, it is obvious that continuous changes in them must be indicative of a corresponding change in the condition of the patient. The arterial pressure is employed almost universally as a measure of the grade of shock. Furthermore, of the recognizable signs of shock, the arterial pressure is the easiest to gauge and to follow in man. For these reasons, and though we agree with Gesell [5] in believing that the circulation may be very seriously disturbed at a time when, through compensatory processes, the arterial pressure is still normal, the arterial pressure has been carefully followed in all of our cases.

For the purpose of following *the arterial pressure* the sphygmomanometer of the author [29] has been employed. The arm band is adjusted to the arm, and, unless it is stated to the contrary, its position is not changed, nor is it tightened or loosened during the entire series of readings. Likewise all of the other conditions affecting the registration of the pressures are kept constant throughout the observations in any given case. The variation in the amplitude of the oscillations, graphically recorded by the instrument in the successive readings, therefore, is an *absolutely objective index* to variations in the condition of the circulation. And, as the amplitude of the maximum oscillation as recorded by the sphygmomanometer under any fixed set of conditions is affected by the pulse-pressure alone, we have in the records as they stand an indication of the condition of the patient's circulation that is quite as significant as the blood-pressure itself.[30] In this respect we are in full accord with Maury and Soulé.[31] While obtaining each record the effort, of course, was made to read the systolic and the diastolic pressures, employing as the criterion of the former the change in the form of the wave [32] and of the latter the first abrupt and consistent diminution in amplitude. It not infrequently happened, however, when the circulation was poor and the recorded pulse amplitude, consequently, was very low, that the diastolic pressure alone could be read. It may be of interest to add that in such instances the pulse either could not be felt at all, or was scarcely palpable, and that attempts to read the pressure by the auscultatory method also failed, and not alone in the case of the systolic pressure but of the diastolic pressure as well.

Blood-pressure readings are subject to a rather large experimental error, especially when the pulse amplitude is small. We therefore desire to emphasize the data that are furnished directly by the pulse amplitude as recorded graphically, rather than those derived indirectly by the readings of manometer. The former, to repeat, are subject to no experimental error and can be interpreted from reproductions of the originals; whereas, the latter

depend upon a judgment made by the observer, which cannot be evaluated by the reader. All of our records, therefore, are published herewith.*

CLINICAL CASES.—Despite the fact that the clinical material of four large St. Louis hospitals has been at our disposal, we have had, since August, 1918, only ten opportunities to administer the gum-glucose solution. As will be seen, many of the cases were really not suited to the purposes of this study. Some of them, without doubt, were not cases of traumatic shock properly so called; pure hemorrhage, fat embolism, toxæmia, and general infection, probably, are amongst the etiological factors. But the cases have not been selected. At first (Cases II–VIII) the gum-glucose solution was given when the surgeon, through whose kindness I was called to see the case, regarded the condition of the patient as desperate, and provided consecutive blood-pressure readings made by myself bore out this opinion by indicating a continuing impairment of the circulation from which spontaneous improvement seemed unlikely to occur. More recently (Cases XI and XII), after experience had given us confidence, the solution has been given when the circulation was seriously impaired, without waiting to see whether the condition was going to be able to take care of itself. Many of the cases I was called to see were not treated because the condition of the patient, as indicated by the arterial pressure, did not seem to be sufficiently aggravated. In every instance, excepting one very flagrant one, cited below, the decision not to proceed with treatment has been justified by the subsequent course of the case. In one instance, in which the patient definitely was in shock, treatment was not given because of internal bleeding. Preparations in this instance were made to start the injection just as soon as the bleeding should be controlled, but the patient died during the operation.

CASE I.—*Crushed foot; shock; not treated.* The first case we were called to see we were unable to treat on account of an accident to the solution on the way to the hospital.† The patient was a colored boy whose foot had been crushed. Apparently there had been relatively little hemorrhage, yet the shock was extreme. The diastolic pressure was about 40 mm. Hg, the systolic pressure could not be determined The pulse amplitude (Fig. 3, records A, B, C) of 1.3 mm. was quite as high as, indeed considerably higher than, in many of our other cases of shock. The patient died about four hours after I had been called to see him.

* The conditions obtaining at the bedside, especially when the patient is desperately ill, are not conducive to the obtaining of unblemished records on smoked paper. The nurse's apron strings, the hand of the restless patient, etc., etc., seem to seek contact with the smoked paper; and the muscular contractions of the patient often cause the recording lever to sweep over the recording surface. The present experiences have led the author to add to the sphygmomanometer certain simple devices which should have the effect of minimizing difficulties of this character. The records reproduced as figure 9 *et seq.* had the advantage of these devices. We ask the indulgence of the reader in respect to the smirches upon the records published herewith.

† This happened before the solution was put up in hermetically sealed containers.

CASE II.—*Gunshot wounds of thigh and buttocks; typical shock.* The patient, a colored male, had suffered considerable loss of blood, though the hemorrhage was not regarded as dangerous. The temperature on admission was 96.8°, but rose to 100.6° just before treatment. The patient was cold, but perspiring freely; his pulse very small, 120 to the minute; the arterial pressures, systolic, 80, diastolic, 70 (records 1, 2, 3, Fig. 3). The diastolic pressure, therefore, was not very low but the pulse pressure was dangerously small. As the patient had been in this condition for some hours without showing any improvement it was decided that something should be done.

It was estimated that the patient weighed 70 kilo. The dose of gum-glucose solution, on the basis of our animal experiments, might therefore have been as large as 350 c.c. given in one hour. As a matter of fact the dose given was 270 c.c. in the course of one hour forty-five minutes. During the administration of the solution the recorded amplitude increased from 1.5 mm. (record 4) to 5.5 mm. (record 35), the pressures, especially the systolic, rising constantly and finally reaching, systolic, 120, diastolic, 85. The pulse-rate, as may be seen by the spacing of the pulses in the successive records, decreased steadily, reaching 77 at 4.20. Three hours later, and the next morning, the pressures were 120, 80–85, the pulse amplitude (new adjustment of arm band), 6.5 mm. All of the shock symptoms disappeared during the injection, the patient falling asleep before its conclusion. There was no temperature reaction to the injection. Recovery was uninterrupted.

CASE III.—*Panhysterectomy; hemorrhage; shock* (?); *infection* (?). White, female. The patient was seen a few hours after panhysterectomy during which there had been considerable and extensive soiling of the peritoneum. Her skin was of a dusky hue, the extremities cold and clammy, the pulse, when palpable at all, thready and uncountable. The diastolic pressure was 50 when the patient was first seen (Fig. 4, records 1–4), falling to 40 later (record 7), and to 30 mm. Hg (record 8) when the needle was inserted into the vein. The systolic pressure was undeterminable. The respirations were rapid, alæ nasi dilating, the temperature 105.6°.

The patient's weight was estimated at about 50 kilo. She was given 200 c.c. of the gum-glucose solution in the course of 1 hour 15 minutes. The recorded pulse amplitude increased from less than 1 mm. (record 8) to over 2 mm. (record 18); and the diastolic pressure rose to 50 mm. Hg, the systolic pressure at the same time becoming legible at 80 mm. Hg. There was possibly a slight improvement in the patient's general condition. The improvement in circulation was not sufficient, however, to hold out much hope for recovery, and it was not maintained. An hour and a half later (record 21) the pressures were 75–45, the amplitude irregular, the temperature 106°. The general condition of the patient was now getting worse again and she died four and a half hours after terminating the injection. There was no autopsy.

CASE IV.—*Primary carcinoma of the liver; splenectomy; shock* (?); *primary and secondary hemorrhage.* White, male. On October 13 splenectomy was done for what seemed to be Banti's disease. The

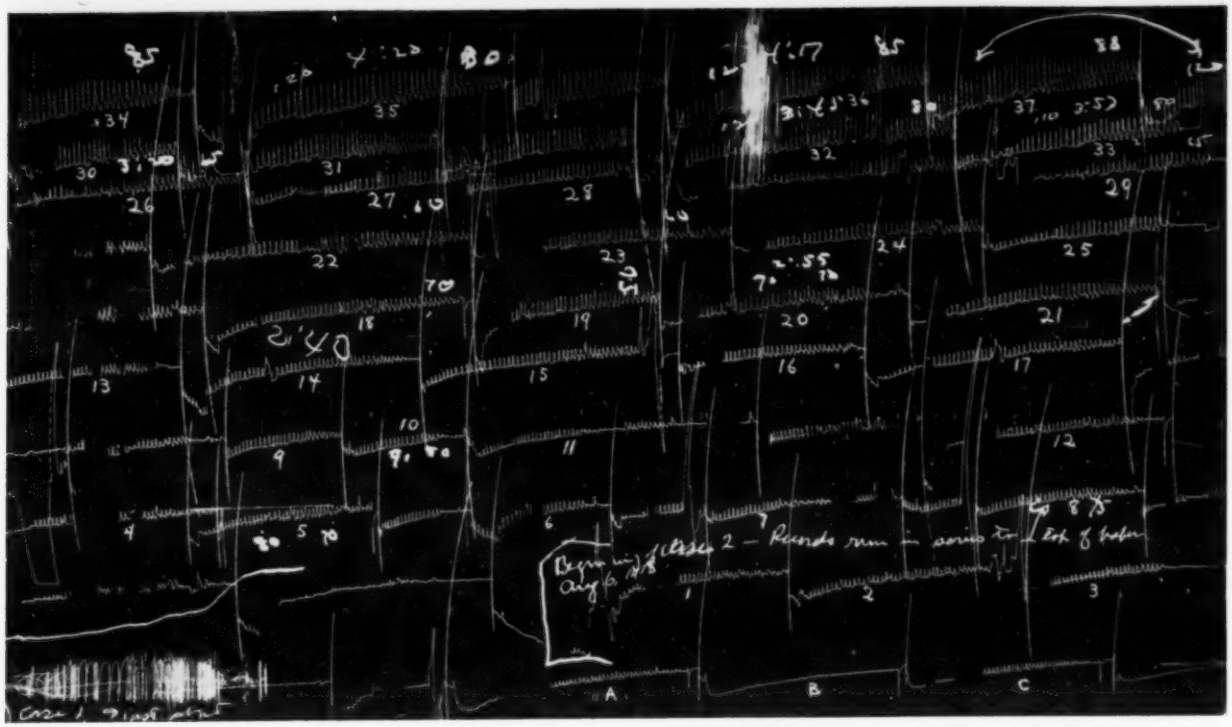

FIG. 3.—Blood-pressure records of Cases I and II. Reduced ⅓, approximately. Read from left to right and from below upwards. Description in text.

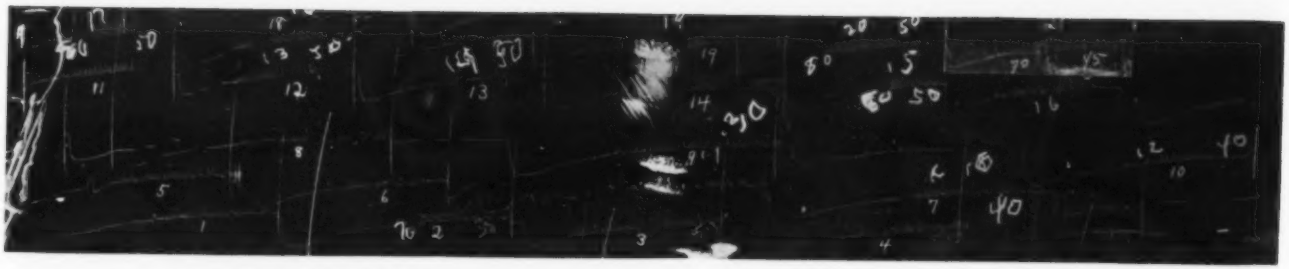

FIG. 4.—Blood-pressure records of Case III. Reduced $\frac{1}{3}$, approximately. Read from left to right and from below upwards. Description in text.

FIG. 5.—Blood-pressure records of Case IV. Reduced $\frac{1}{5}$. Read from left to right and from below upwards. Description in text.

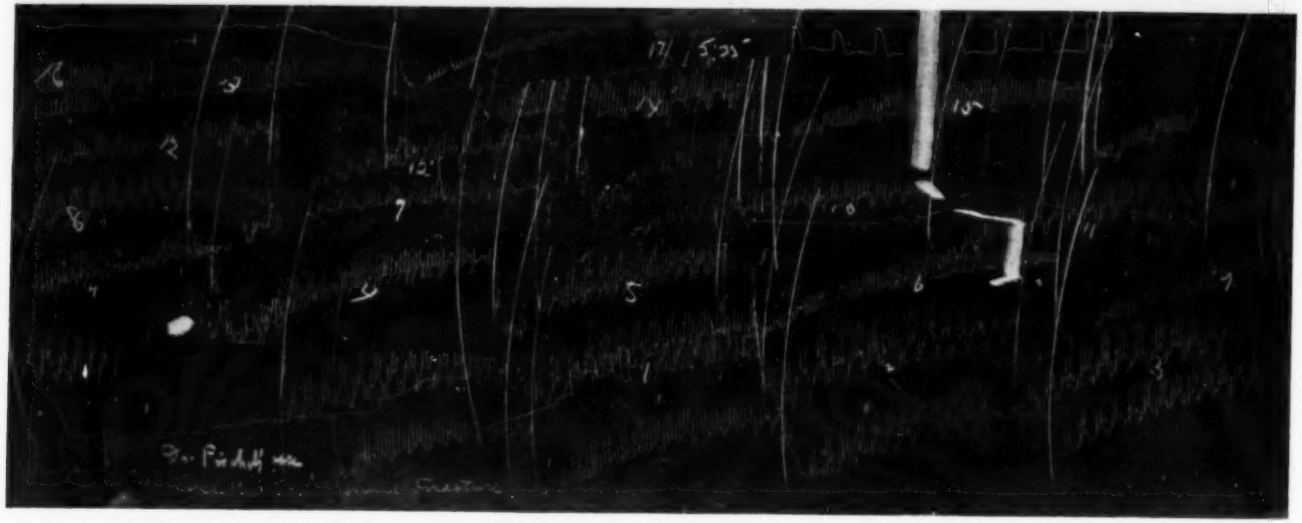

FIG. 6.—Blood-pressure records of Case V. Reduced ⅕, approximately. Read from left to right and from below upwards. Description in text.

FIG. 7.—Blood-pressure records of Case VI. Reduced $^1/_{10}$. Read from left to right and from below upwards. Description in text.

spleen was everywhere firmly adherent; the operation, consequently, was difficult, and the patient lost a great deal of blood. He did fairly well on the first day. On the second day, the note was made—"At 9 A.M. to-day the patient was *in extremis*. His pulse was thready and almost imperceptible; he looked pale and cold. This condition developed about 2 A.M. Though the patient was a little better at 1.15 P.M., it seems wise to try Doctor Erlanger's treatment."

When the patient was first seen by the author his condition seemed serious. His pulse was weak—120 per minute—he was cold, and he felt that he was going to die. He was vomiting some bloody material. His pressures were 100–80. The amplitude of oscillation (Fig. 5, up to record 4) varied somewhat from record to record; it was not as small, however, as in some of our other cases. If the patient was not in shock, he was in what was regarded as a condition closely approaching it. It was, therefore, decided to administer the gum-glucose treatment.

The patient received 200 c.c. in the course of one hour ten minutes. More might have been given, but it was not regarded as necessary. Hypodermoclysis also was started while the solution was being administered. The pulse amplitude increased steadily during the injection, growing from 2.0–3.0 mm. (record 4) at the start to 5.0–5.5 at the finish (records 25, 26). The pressure readings at this time were 110, 80–85. The pulse-rate also diminished somewhat, from 120 to 105. The patient fell asleep toward the end of the period. Some three hours later (record 28) the pulse amplitude and the blood-pressures had receded somewhat; they were 4.0–4.5 mm. and 100, 80. The clinical note on the patient's condition reads: "Doctor Erlanger called to see the patient, advised gum-glucose treatment, treatment given, patient rallied."

The next morning (October 16) the patient's circulation was much improved, the pulse amplitude (new adjustment of arm band, see record 29) was 8.5 to 9.0 mm., the pressures 120–80; the pulse-rate, though, was still quite rapid, 120 per minute. The patient did fairly well during the 17th, though some blood continued to appear in the vomitus. On the morning of the 18th, he vomited 300 c.c. bright red blood; on the 19th he became irrational and violent, and as a result his wound broke open, and he died that day. There was no temperature reaction to the injection, the temperature remaining normal for twenty-four hours, rising to 101°, 100°, 100°, respectively, on the three following days.

TABLE II

ESTIMATIONS OF THE RED CORPUSCLES, HÆMOGLOBIN AND CLOTTING TIME, CASE IV

Date	R. B. C. per mm.³	Hb., per cent.	Clotting time
October 14	5,340,000	85	..
October 15	4,032,000	65	..
October 15 (2.00 P. M.)	4,608,000	75	5′
October 15 (9.15 P. M.)	4,056,000	75–80	7′
October 16	3,860,000	70–75	4′–20″
October 17	2,720,000	65–70	..
October 18	2,816,000	70	..
October 19	1,912,000	40–50	..

Estimations of the red corpuscles, hæmoglobin and clotting time are shown in Table II. It is seen, if allowance be made for experimental error, that the patient steadily lost blood, and that the clotting time was not affected by the injection.

At autopsy there was found primary carcinoma of the liver with metastases to the diaphragm and lung; cirrhosis of the liver; ruptured œsophageal varices; hemorrhage into the stomach and at the site of the splenectomy; general arteriosclerosis; and chronic interstitial nephritis.

To summarize, during the injection of somewhat less than 3 c.c. per kilo of body weight, 200 c.c. in all, of the solution, the circulation was decidedly improved though part of the improvement was lost subsequently. Some twelve hours later the pulse amplitude and the blood-pressures were found to be normal, though the pulse-rate remained high. These changes occurred despite evidence of continuous secondary hemorrhage which had begun before treatment and which apparently was not aggravated by the treatment. It is obvious that the whole of the recovery of the circulation was not attributable to the gum-glucose; it is quite possible, though, that by the treatment the patient was tided over the critical stage of the post-operative period. Death was due to secondary hemorrhage from ruptured vessels.

CASE V.—*Compound comminuted fractures; shock or fat embolism.* White, male. At midnight I was called to see a " case in shock with low pressures." The patient was a man who had been struck by an automobile and had sustained compound comminuted fractures of the left thigh and of the right leg. I saw him at about 1 A.M. He was then under ether and the operation was well advanced. The pulse was good, the arterial pressures 140, 90, the recorded amplitude 6.0 mm. (Fig. 6, record 1). I decided that the patient was not in shock despite the insistence of the surgeon to the contrary, who now based his opinion upon the observation that the skin incisions did not bleed. Table III and the records (Fig. 6) show that for a time the circulatory conditions remained constant. Later (record 4 *et seq.*), the pressures and the recorded amplitude started downwards. At 2.35 (record 12) the pressures were 90 (palpatory), 65, the amplitude 3.8 mm. The patient now began to struggle, so that pressure estimations could not be made until he was quieted, one hour twenty minutes later, by repeated doses of morphine. In the interval, judging by the pulse, the patient's condition grew steadily worse and preparations were made to inject the gum-glucose solution. The records, therefore, do not show the patient's circulation at its worst. At 3 A.M., when injection of the mixture was started, the patient was blue, pulseless, and gasping. By 3.42, 90 c.c. had been given, and the pulse was better and constantly improving. By 3.56 the patient had quieted down and we succeeded in obtaining record 13. The diastolic pressure alone was legible; it was 60 mm. Hg the amplitude 6.0 mm. Record 14 was obtained at 4.12, the pressures being 95 (palpatory), 60, the amplitude 6.0 mm.; record 15 at 4.23, the pressures being 90 (palpatory), 65, the amplitude 5.2 mm. At this time the injection was ended, the patient having received 265 c.c. The pulse was now fair, but did not feel normal and it was still quite

rapid. Neither were the pressures normal; the respiration, though, was much improved. It was decided not to give more of the solution, however, but to wait and see how the patient reacted. The pressures, though, started to fall again immediately after terminating the treatment, the diastolic pressure being 60 and the amplitude 4.5 at 4.42 (record 16); and 55 and 4.0 at 5.35 A.M. The interne was instructed to follow the pressure and to inform me if it fell any further. This was not done, despite the note in the history made at 7.15 A.M.—"pulse very weak, 136, respiration somewhat labored." It was not until 12 M. that I was called to the hospital. It was 1 P.M. when I reached the

TABLE III

DATA OF CASE V

Record No.	Time A. M.	Pressures		Ampl. mm.	Remarks
		Syst. mm. Hg	Diast. mm. Hg		
1	1.08	140	90	6.0(?)	
2	1.09	140	95	8.0	
3	1.15	140	95	7.5	
4	1.30	135	90	5.5	
5	1.31	135	90+	6.0	Arm band tightened here.
6	1.45	120 (?)	80	5.0	Anæsthetic off. Applying plaster casts.
7	1.50	115 (?)	80	5.3	
8	2.00	110 (?)	80+	5.0	
9	2.10	?	70 (?)	4.0	
10	2.20	?	60–70	5.0	
11	2.30	?	70	4.5	
12	2.31	90 palp.	70	4.0	
12′	2.35	90 palp.	65	3.8	No more records until 3.56 on account of struggling of patient. Pulse steadily becoming worse
	3.00				Patient pulseless and gasping. Starting gum-glucose.
	3.42				Pulse better. 90 c.c. in.
13	3.56	?	60	6.0	
14	4.16	95 palp.	60	6.0	Patient quieter, has had gr. ½ morphine. 215 c.c. solution in.
15	4.23	90 palp.	65	5.2	265 c.c. in. Injection ended. Carotids throbbing, pulse still rapid. Started giving 21 oz. saline hypo.
16	4.42	?	60	4.5	
17	5.35	?	55	4.3	In bed. Has had 1 gr. morphine

ward and the patient then was dying. It was too late to start a second injection. There was no autopsy. This note occurs in the history: "The patient passed into a state of shock and was treated for the same while in the emergency room, and later was sent to the ward in fairly good condition, but became progressively worse and died at 1.25 P.M."

The cause of the collapse in this case is not entirely clear; it may have been shock, properly so called, or it may have been fat embolism.[33] But whatever the cause, it is clear that, though the gum-glucose solution undoubtedly improved the circulation, the gain was not as complete as might have been desired, nor was it maintained. There was no temperature reaction to the injection.

CASE VI.—*Intestinal obstruction; shock* (?). White, female. This was a case of intestinal obstruction of over five days' duration. There had been fecal vomiting. The temperature was 97°. I was asked to be present at the operation because the surgeon anticipated trouble. The operation, consisting of a lateral anastomosis of the small intestine, was performed under morphine-scopolamine anæsthesia. The upper part of the bowel was greatly distended; no attempt was made to draw off its contents. The patient was quite restless, and it therefore was difficult to obtain good blood-pressure records, especially toward the close of the operation.

In Table IV are given the blood-pressure readings and the maximum amplitude of the records shown in Fig. 7. It is seen that at first the readings were well within the normal range. At about the time the operation began the pressures and the oscillation amplitudes (record 5) started to fall, and it was not long before the pulse could not be felt and before the systolic readings became very difficult. The diastolic pressure, though, could be read with a fair degree of accuracy at all times; it fell from 100 to somewhere between 70–80 mm. Hg, where it remained, possibly rising a bit toward the end of the injection. With the diastolic pressure as a basis, the variations in the systolic pressure can be inferred from the variations in oscillation amplitude. It thus can be seen that the systolic pressure, and consequently the pulse pressure, were lowest at about the time (record 13) the administration of the gum-glucose mixture was begun. They then increased more or less constantly during the injection which terminated with record 23. It is obvious, therefore, that the injection caused a decided improvement in the circulation, though it did not bring it back to normal. At 10 A.M., that is, seven and a half hours after terminating the treatment, the report was received that the patient was doing well. But the notes in the history show that, whereas at 4 A.M., and again at 5.30, the pulse was of "fairly good volume, 140," at 8 A.M. it was "very weak and irregular." The temperature now, about five and a half hours after terminating the injection, was 99.4°. At 12 M. "the skin was cold and clammy, pulse almost imperceptible, the respiration slightly labored." At 1 P.M., almost eleven hours after treatment, the rectal temperature was 105.8°, and at 2.15 P.M. the patient died.

The rise in temperature requires a word by way of comment. There are a number of reasons for not regarding it as a reaction to the injection. The most important of these are: (*a*) The phases of an anaphylactic reaction are very much shorter than in this case; (*b*) the temperature reaction to bacteria-containing salt solutions is not so severe.[34] As there was no autopsy it is impossible to reach a definite conclusion with regard to this question.

CASE VII.—*Cerebral exploration; hemorrhage; shock* (?). White, female. At 9.30 A.M. an extensive, rather bloody brain operation had been performed. Immediately after the completion of the operation, at about 12 M., the patient's pulse was weak and I was called to see her. The records marked "12.30" (Fig. 8) were then obtained. The pressure readings corresponding with them were 105, 80 and 100, 75.

TABLE IV

DATA OF CASE VI

Record No.	Time P. M.	Pressures		Ampl. mm.	Remarks
		Syst. mm. Hg	Diast. mm. Hg		
2	11.38	130	100	8.0	Before operation, patient on table under morphine-scopolamine
3	11.40	130	100	8.0	
4	11.45	125	100	8.0	
5	11.47	125	100	7.0	Operation started
5′	11.49	125	100	7.0	
6	11.52	120	100	5.5	
	A. M.				
7	12.07	...	90	2.5	Pulse 140
8	12.39	110	90	4.5	
9	12.53	?	80	2.5	Pulse 150
10	1.02	90 palp.	80	3.0	
11	1.20	...	80	1.5	After this tightened arm band.
12	1.22	...	80	2.0—	
	1.30	...	...	...	Starting gum-glucose
13	1.31	...	80	1.3	
14	1.40	?	?	1.0	
15	1.48	...	70	2.5	
16	1.50	...	80	2.5	
17	1.55	...	80?	2.5	
18	2.03	...	80	3.0	100 c.c. in.
19	2.04	100	80	3.0—	
20	2.15	...	70	3.5	
21	2.16	...	70	4.0	
22	2.17	85	70	3.0	
23	2.24	90	75	3.5	
	2.29	...	...	...	200 c.c. in. Injection ended
24	2.30	...	75	4.0	Pulse 150
25	2.31	...	80	4.0	
26	2.35	...	80	3.5	Record not satisfactory

As the patient presented none of the symptoms of shock, and as the circulatory conditions did not seem to be especially threatening, it was decided to do nothing except administer fluids in the usual way. At 6 P.M. the patient's pulse was found to be "imperceptible" and I was asked to see her again. The records marked 6.20 were now obtained. The systolic pressure could not be determined accurately but it is obvious from the record, both on account of the low amplitude and of the shortened phase of oscillations, that it was very close to the diastolic pressure which was 75. Her pulse pressure obviously was dangerously small.

Preparations were immediately made to administer the treatment. Owing to the inconspicuousness of the veins it was necessary to cut through the skin in order to insert the needle. At 6.30 the injection was started. The records (numbers 3–6) made during the first ten minutes showed such great variability that instability of the pressures, such as cerebral cases commonly exhibit, was suspected. Record 7, made with a constant, optimum (diastolic) pressure upon the arm, confirmed this suspicion. The patient received 250 c.c. of the solution

in the course of one hour twenty minutes. This was close to the maximum dose, for the patient probably did not weigh more than 45 kilo. Fig. 8 shows the continuous improvement in the circulation during the injection, which terminated with record 24. The readings made with this record were 100, 78. Records 25–27, made two hours later, showed further improvement in the circulation, the pressures with these being 110, 75. The next morning record 28 was obtained; as this was made after a readjustment of the arm band the amplitude of oscillation is not entirely comparable with that of the previous records. It is obvious, however, that in this respect the circulation was quite normal. The corresponding pressures were 105, 78. There was no temperature reaction to the injection, the temperature before being 99.6°, and after, 99.2°. During the same night and the succeeding night the temperature rose to 100.8° On the day following the treatment the note was made—" patient in good condition." The patient recovered completely from the effects of the operation, and was discharged from the hospital.

CASE VIII.—*Carcinoma of the rectum; hemorrhage; shock.* White, female. At 12.05 P.M., January 20, a Kraske operation was performed involving resection of the coccyx, a piece of the sacrum, about a foot of the rectum, and the posterior vaginal wall. It was necessary to enter the peritoneum. There was considerable loss of blood and " the patient was considerably shocked." I was called to see her at 3.30 P.M. and made the records labelled A (Fig. 9). The pressure readings were 80, 65. Her condition evidently was serious but it was decided to observe the trend of things before interfering. At 4.20 P.M. her pulse was 170, her " respiration jerky and shallow;" it was scarcely possible to get a pulse with the sphygmomanometer (see record 1). The diastolic pressure, roughly, was 5 mm. Hg, the systolic pressure could not be estimated. At 4.35 the administration of the gum-glucose solution was begun and in the course of two hours twelve minutes 220 c.c. were given. Owing to mechanical difficulties the rate of injection was much slower than was necessary. It was estimated that the patient received somewhat less than 5 c.c. of the solution per kilo of body weight. The injection terminated at 6.47 (record 28), when the blood-pressures were 100, 78, the pulse amplitude 3.0–4.0. The steady improvement during the treatment is clearly indicated by the figure. Records 29–33, made three hours later, with readings of 95, 70, and 3.0 mm., show that little, if any, of the improvement had been lost in the interval. Records 34–37 were made the next morning while the patient was nauseated. The systolic pressure ranged in the different estimations between 95 and 100 mm. Hg, the diastolic, between 75 and 80; the amplitude was 3.0 mm. In the evening the pressures were 110, 80. There was no temperature reaction to the injection. The clinical note made at 11 P.M. on the night of the operation reads, " Patient improved, condition now fair, pulse of fair quality—130–140." It should be added that the patient received 1000 c.c. salt solution subcutaneously while the gum-glucose solution was being given. A similar dose of salt solution was again given at 11 P.M.

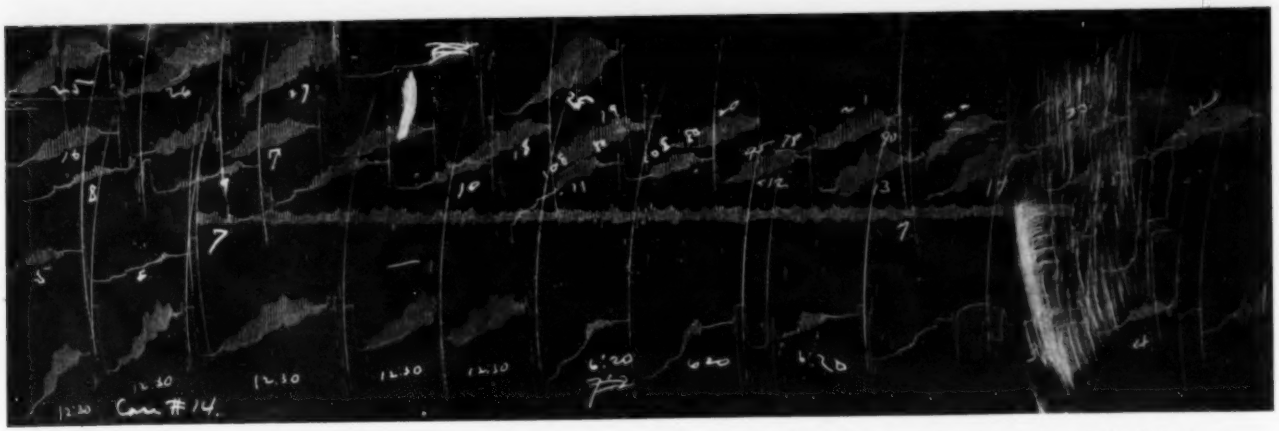

FIG. 8.—Blood-pressure records of Case VII. Reduced ⅓. Read from left to right and from below upwards. Description in text.

FIG. 9.—Blood-pressure records of Case VIII. Reduced ⅓, approximately. Read from left to right and from below upwards. Description in text.

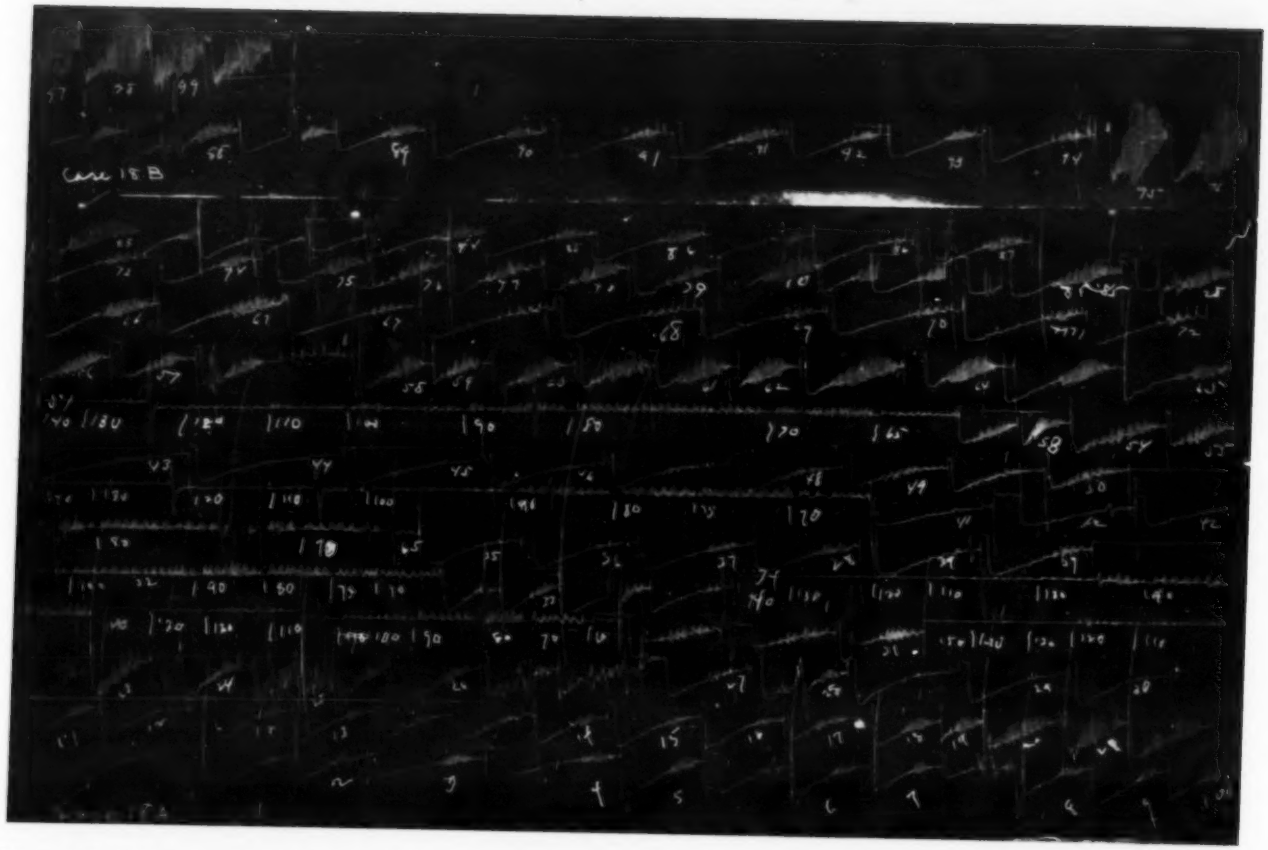

FIG. 10.—Blood-pressure records of Case X. Reduced ¼, approximately. Read from left to right and from below upwards. Description in text.

The patient did well for four days, when symptoms of peritonitis developed. She gradually lost ground and died two weeks after the operation. Blood cultures made on the fifth day were negative.

CASE IX.—*Vaginal resection of cervical stump for carcinoma; hemorrhage; not treated.* White, female. The operation consisted of a very difficult vaginal resection of the cervical stump for recurrent carcinoma. There had been considerable hemorrhage during the operation, and an apparently profuse secondary hemorrhage from the vagina, subsequently. I saw the patient at 2.15 P.M. The pulse could scarcely be felt at the wrist and the sphygmomanometer recorded only the faintest flutter of a pulse. The arterial pressure could not be determined by any method whatever. The patient was conscious and somewhat restless. The skin did not feel cold. It was obvious that she was suffering from an extreme, acute hemorrhage, and transfusion of blood was advised. I was told that the preparations would require about a half hour. As I felt the patient could wait that long the gum-glucose solution was not given. But there was one unavoidable delay after another, and after each it seemed as though the transfusion would be started without further delay. But the result was that the transfusion was not started until 4.58 and the patient then was dying.

This unfortunate experience teaches the lesson that even when, in any given case, transfusion of blood is clearly the preferred treatment, the thing to do, pending preparations for blood transfusion, is to at once transfuse a blood substitute, such as simple saline, or better, isotonic gum-saline or hypertonic gum-glucose solution (cf. Case X). This case, in a way, may be regarded as another control (see Case I) to our series of treated cases. It will be noted that death occurred about three hours after I had been called to see the patient. It was the earliest death of the whole series.

CASE X.—*Excision of osteoma of cranium; extreme hemorrhage; shock* (?). White, female, age sixty-one years. On March 3 an attempt to excise a bony tumor overlying the superior longitudinal sinus had to be interrupted on account of hemorrhage. I was called to see the patient immediately after this operation and after she had been transfused with blood. But her pressures were systolic 140–130, diastolic 100–90; and she presented none of the symptoms of shock. On March 6, the operation was completed. The hemorrhage again was extreme. Although the patient had already received 250 c.c. of blood, the pressures at 11 A.M. were about 85 (systolic) and 70 (diastolic), and the recorded amplitude (records 1–11, Figs. 10 and 11) was only 2 mm. Compared with those obtained three days earlier, these values were extremely low.

At 11.53, when her pulse pressure had decreased to 10 mm. Hg and the recorded pulse amplitude was decreasing, a second transfusion of citrated blood, taken from a matched donor, her son, was begun. In the course of ten minutes the patient received 450 c.c. of blood. During the injection (records 15–21) the pressures rose to 110, 80 mm. Hg, the amplitude becoming 6 mm. These pressures, however, did not hold. Within twenty-one minutes (record 24) they had fallen to 90, 75; the

amplitude to 2.5 mm.; and the pulse was 180 per minute. The patient now had a chill which for some time interfered with the obtaining of blood-pressure readings. Her temperature, which had been normal, at 1.30 was 102.4° F., at 7 P.M. 104°, and at 10 P.M. 100.8° (see Fig. 11). After the chill the recorded pulse amplitude diminished, to all intents and purposes, progressively (records 28–42) until, by 2.58 (record 42), the recording lever showed only the faintest oscillation on a diastolic pressure of about 65. The respirations now were 38 per minute and often periodic; the skin wet and cold. The patient was completely unconscious; there was no corneal reflex and no reaction to incision of the leg for the purpose of exposing the vein.

The injection of gum-glucose solution was started at this time. In the course of one hour eight minutes she received 275 c.c., when, on account of a leak in the vein, the injection was temporarily discontinued. During the injection the diastolic pressure rose (records 43–54) from 60 to 70 mm. Hg, the systolic to 105, the recorded amplitude increasing from practically nothing to 2.5 mm. The patient regained consciousness and did not again lose it. Later (4.45–5.37) the injection was completed. The total dose amounted to 300 c.c.; but the amount given after 4.05 was so small and the rate of its administration so slow that to all intents and purposes 4.05 marks the end of the injection. From about 3.25 (record 47) and until 5.37 (record 63) there was a progressive improvement in the circulation, the amplitude of oscillation and the pressures becoming quite as good as during the twelve-minute period of rapid blood injection. This improvement occurred despite the concurrent reaction to the blood injection. But now, during the height of the temperature reaction, the pressures fell (records 63–71), reaching the low point of 48 mm. Hg (diastolic) at 6.15. At this time the recorded amplitude was 1.6 mm.; it was not nearly so small as it had been during the period of low pressure that developed after the blood injection. Now the circulation began to improve again (records 71–83), so that by 7.55, the pressures had risen to 100, 70, the amplitude to 3–4 mm. The pulse-rate was 148; the respirations, 32. This improvement again was succeeded by a recession, the pressures, by 9.55 P.M., falling (records 84–94) to 70, 55, the amplitude to 1.5 mm. Periodic respirations were again noted.

During the remainder of the night systolic blood-pressure readings were made by the nurse by the palpatory method. Checked against the readings by the recording sphygmomanometer the former were about 10–15 mm. Hg too low. Bearing this in mind, it becomes obvious (see Fig. 11) that a slow and steady improvement in the circulation began within two to three hours of the termination of my readings, the systolic pressure rising from 70 at 10.30 P.M., March 6, to reach 118 at 6.30 A.M., March 7. At 8.40 A.M. readings with the recording sphygmomanometer (new adjustment of arm band, records 95–97) showed pressures of 120–130 (systolic), 70–80 (diastolic) and a pulse amplitude of 23 mm. The circulation evidently had become normal and it remained so. The patient's temperature reached normal on the third day, and remained normal for twenty-four hours; her pulse-rate remained at the high

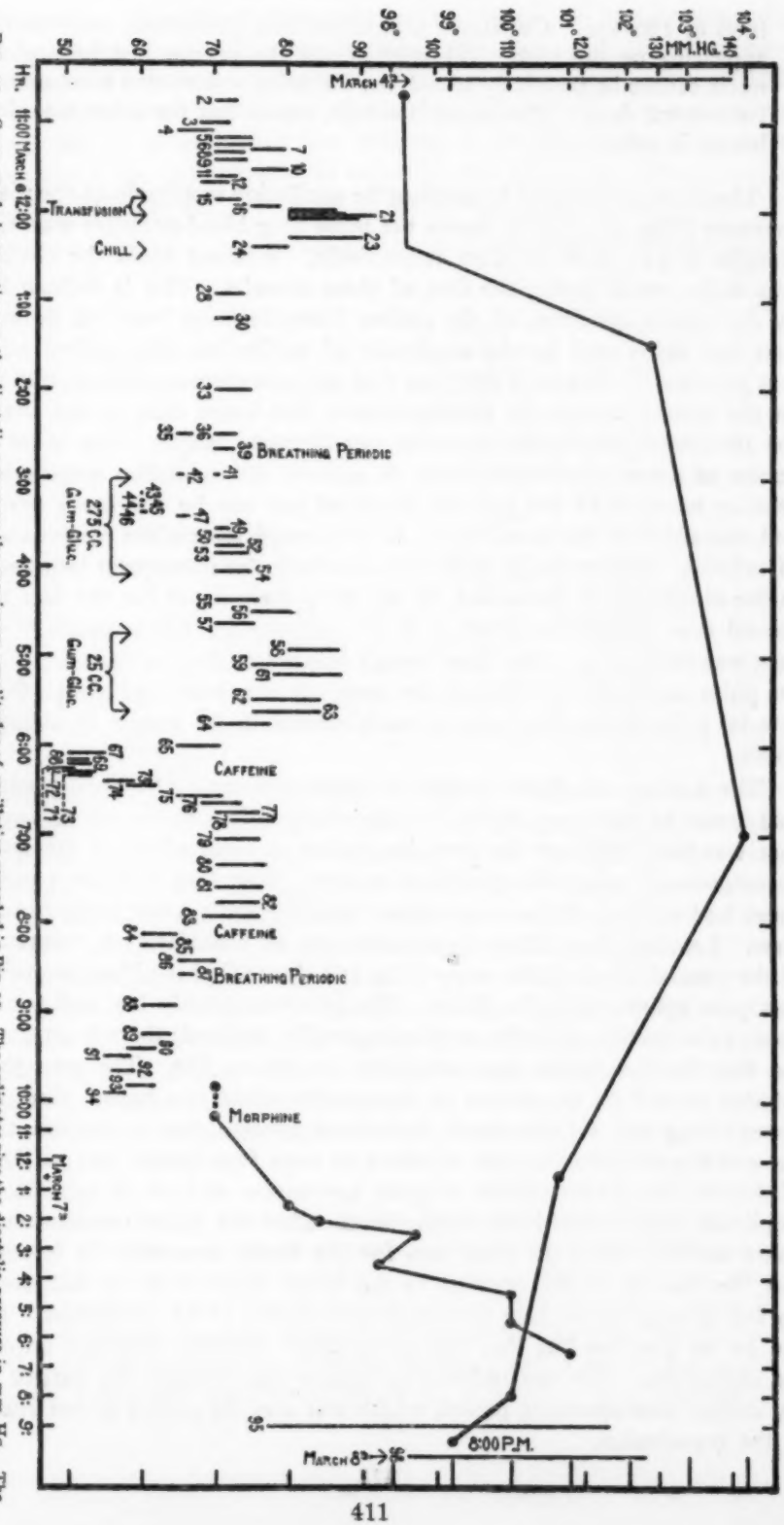

FIG. 11.—Curve made by erecting on the diastolic pressures the maximum amplitudes of oscillation recorded in Fig. 10. The ordinates give the diastolic pressure in mm. Hg. The scale of amplitude is such that 1.0 mm. of amplitude is subtended by 20 mm. Hg. Note that after 10:00 P.M. the time scale changes; this has the effect of making the final rise in pressure appear much steeper with respect to the rest of the curve than it actually was.

level of 120–130. On March 9 jaundice was first noted; this was disappearing on the 11th. Whether or not the patient had hæmoglobinuria cannot be positively stated, for the urine was voided involuntarily for several days. The nurse, however, states that the urine was dark brown in color.

The curve constructed by plotting the oscillation amplitude on the diastolic pressure (Fig. 11) clearly shows the three long blood-pressure waves, with troughs at 3.10, 6.08 and 9.40, respectively. Without doubt the circulation was at its worst during the first of these troughs. This is indicated both by the mental condition of the patient (consciousness was lost during the first fall only) and by the amplitude of oscillation (the patient actually was pulseless). It was at this time that the gum-glucose solution was given. In the second trough the blood-pressures fell lower than in the first, but the oscillation amplitude remained considerably larger. The latter is a matter of some significance, since, in general, the oscillation amplitude is a relative measure of the amount of blood put out by the heart per beat, and, therefore, of the blood flow. In this trough the patient received a dose of caffeine. One might be inclined to attribute the subsequent improvement in the circulation to the action of this drug were it not for the fact that a second dose of caffeine, given at 8, did not stay the fall in pressure which then was under way. The third trough was not as deep as the second, while the pulse amplitude in both was the same. It was from this trough that the arterial pressure steadily rose to reach normal in the course of about nine hours.

The etiology of these troughs is quite obscure. The only suggestion that seems to have any degree of plausibility refers them, not to anything that was being done at the time, but rather to some effect of the cerebral decompression upon the medullary centres. The fact that the patient at times had Cheyne-Stokes respiration, possibly lends some support to this view. Leaving these sharp depressions out of consideration, examination of the general trend of the curve (Fig. 11) shows that the blood transfusion was quite ephemeral in its effects. The gain was quickly lost and for three hours subsequently the pulse amplitude steadily declined; there is no question but that the circulation was insufficient to sustain life. The gum-glucose solution caused the circulation to improve for about two hours; then, again disregarding the (presumably) fortuitous troughs the circulation slowly but steadily declined through a period of over four hours; but at the end of this decline the circulation was not any worse, at least as regards pulse amplitude, than it had been forty minutes after the blood transfusion nine hours earlier. Then the final turn for the better occurred. It is possible that the waning of the reaction to the blood transfusion, as indicated by the fall in temperature, here facilitated the recovery of the circulation. There can be no question but that the gum-glucose solution markedly improved the circulation. We are inclined to believe that it tided the patient over her critical post-operative period, which was also the period of her reaction to the transfusion.

The results of the blood examinations, taken from the history, are given below in tabular form. The hæmoglobin estimations are somewhat more consistent than the red cell counts. We, therefore, base our discussion upon the behavior of the former alone. If we leave out of consideration, as being difficult of evaluation, the influence of the blood transfusions and of destruction and regeneration of red-cells, and regard the dilution of the blood as an index to the restoration of the blood-volume, it seems justifiable

Date	R. B. C. per mm.³	Leuc. per mm.³	Hb. per cent.
February 28	4,432,000	11,800	85
March 4	3,424,000	15,600	76
March 6	2,048,000	6,100	56
March 7	2,496,000	.....	49
March 8	1,798,000	.....	43
March 9	1,504,000	20,150	39
March 11	1,728,000	16,850	40
March 12	1,776,000	.....	42
March 13	1,952,000	15,000	42
March 14	1,964,000	16,700	42
March 15	1,620,000	12,400	36
March 16	1,760,000	11,800	37
March 18	1,824,000	12,500	41
March 19	1,312,000	9,750	38
March 20	2,048,000	9,980	38
March 21	2,853,000	10,500	20
March 22	2,240,000	8,750	23
March 22	1,744,000	14,950	42
March 23	2,112,000	16,080	25
March 24	.....	29,450	..

to infer that with the first hemorrhage (March 3) the patient lost about one-ninth of her total blood-volume, and with the second hemorrhage (March 6) a bit less than one-half of the blood-volume remaining. In the two hemorrhages considerably more than one-half of the total blood-volume was lost. The count of March 6 was made about twelve hours after the second hemorrhage and shortly after the administration of the gum-glucose solution. It shows that considerably more than 57 per cent. of the blood-volume finally attained had by then been acquired. Just how much of this rapid restoration of blood-volume is to be attributed to the action of the gum-glucose solution and how much to natural processes it is impossible to say. Nucleated red cells were found March 8.

On the fourth day the patient's temperature started on a more or less steady rise and reached 102°–103° on the eleventh day, where it remained until the nineteenth day. At, or shortly after, the time the temperature began to rise, a badly infected sore developed on the patient's buttocks; by the thirteenth day this had broken down; and on the sixteenth day it had to be incised. On the thirteenth day some serosanguinous fluid was removed from the wound in the leg from which the piece of muscle, used to stanch the hemorrhage from the longitudinal sinus, had been removed. On the twentieth day a small area of the patient's scalp was found to be sloughing. A blood culture, made on the

fourteenth day, proved negative. A thorough physical examination seemed to exclude all of the common causes of the febrile condition excepting the skin infections and the anæmia, which had persisted despite the administration of iron. The convulsions, which had been a part of the patient's pre-operative clinical picture, persisted after the operation.

On the nineteenth day the patient, now in an extremely weakened state, was again transfused with blood taken from a rematched donor, again a son. The temperature rose immediately to 106°, fell to 101° eight hours later, and then rose steadily to reach 106.8° in three days, when the patient died, twenty-two days after the second operation. There was no autopsy.

CASE XI.—*Excision of endothelioma of the dura; shock* (?). White, female. During the excision of the tumor, under ether anæsthesia, the patient's systolic pressure, taken from the leg by the auscultatory method, fell from 160 to 92 mm. Hg, and then could not be estimated at all. There had been relatively little hemorrhage. At this time the diastolic pressure, taken in the leg by the oscillatory method, was 75 mm. Hg, the systolic pressure could not be determined (records A to E, Fig. 12). Records F to I were taken from the arm while the patient was still in the operating room. The diastolic pressure was 70, the pulse amplitude 1.0 to 1.5 mm. Records 1 to 4 were taken between 12.12 and 12.18, after the patient had been put to bed (readjustment of arm band). The diastolic pressure was still 70 and the pulse amplitude 1.5 mm.

I felt that the patient's condition was not urgent and that it would do no harm, before interfering, to determine her trend. But in view of the results of treatment previously observed, the surgeon requested that the gum-glucose solution be given at once. At 12.18 the needle was inserted into the vein transcutaneously and the injection started, but as the fluid seemed to be going into the tissues, the injection was discontinued after about 50 c.c. had left the bottle. At 12.30 the injection was started again, now, into the exposed vein. The pressure and the pulse amplitude had not changed in the interval. In the course of an hour, 212 c.c. more of the solution were injected. During this time (records 5 to 16) the pulse amplitude increased steadily until it became 4 mm. The diastolic pressure rose to 80. The systolic becoming legible at 90, at 12.38, increased steadily and reached 110 at 1.31. The blood-pressure readings made after terminating the injection were as follows:

Record No.	Time	Syst. mm. Hg	Diast. mm. Hg	Max. ampl. mm.
18	1.35 P. M.	115	85	3.5
19	2.00 P. M.	110	85	3.0
20	2.20 P. M.	115	88	3.4
21–22	3.50 P. M.	105	75	3.5
23–24	5.20 P. M.	110	80	4.0
25–27	8.00 P. M.	125	90	5.5
28–29	9.00 A. M.	115	85	6.0 arm band readjusted

FIG. 12.—Blood-pressure records of Case XI. Reduced ¼, approximately. Read from left to right and from below upwards. Description in text.

FIG. 13.—Blood-pressure records of Case XII. Reduced ²/₃. Read from left to right and from below upwards, as numbered. Description in text.

These readings show very slight, if any, retrogression during the first two hours or so, and then a steady improvement.

The patient's temperature rose gradually to reach a maximum of 102.6° at 8 P.M. on the first day. It remained there for about twelve hours, then slowly and steadily fell, and became normal on seventh day. The slow defervescence indicates that the rise was not in the nature of a reaction to the injection.

CASE XII.—*Operation for sarcoma of the uterus; hemorrhage; shock* (?). Colored, female. The operation consisted in the partial removal of a huge sarcoma of the uterus, which seemed to be aggravating a mitral regurgitation and to be causing, or aggravating, a marked renal insufficiency. During the operation an infected ovarian cyst was accidently ruptured. There was considerable hemorrhage. I was called to see the patient during the operation, when her pulse could no longer be felt nor her pressure determined (auscultatory method). Records 1 and 2 (obtained at 9.25 A.M.) showed the pressures to be 75 (systolic) and 50 (diastolic); the amplitude was 4.5 mm. (Fig. 13). Twelve and fourteen minutes later (records 3 and 4) the pressures were 65, 50 and 60, 45, respectively, the amplitudes, 3.5 and 4.0 mm.

Again I felt that it would do no harm to follow the trend of things before interfering, but the surgeon requested that the gum-glucose solution be given. Between 9.40 and 10.50, 210 c.c. were administered. The pressures (records 4 to 14) improved promptly, and more or less steadily, so that when the injection was terminated they were 105, 80, and the pulse amplitude 10.5 mm. About a half hour subsequently the pressures fell somewhat to reach 85 and 65, but the amplitude diminished very slightly, to 9.0 mm. (record 20). They then improved so that by evening (arm band readjusted) they were 100, 5 mm. Hg and 8.5 mm. The next morning (readjustment of arm band) they were 105, 76 and 10.0 mm. The pre-operation pressures had been 104, 70. Despite an unabated renal insufficiency indicated by 83–86 mgr. non-protein nitrogen per 100 c.c. blood, and by a phenolsulphonephthalein output of only 5 per cent. in two hours, the patient made perfect progress for 21 days, when she contracted pneumonia and died on the 25th day. At autopsy a fresh lobar pneumonia and very marked hydronephrosis were found.

Cases of Cholera Infantum.—The two following cases are included in this paper, not because they bear on the treatment of shock, but because they furnish valuable evidence of the harmlessness of the gum-glucose solution. The reasons for administering the solution will probably be published in due time. These cases were not seen by the author. They were in the service of Dr. W. McK. Marriott to whom we are indebted for the following note:

"We have injected the 18–25 per cent. glucose-acacia solution into two infants suffering from alimentary intoxication (cholera infantum). Both were in a state of collapse with feeble pulse, gray skin, great desiccation. The clinical results were good. One of these infants at the time of injection

was in a semicomatose state. He became conscious shortly after the injection. In both instances there was a distinct change in the character of the pulse. From a weak, thready pulse, it changed to a full one. One of these infants had previously received a glucose solution with good effect; but the effect was not so lasting as that of the glucose-acacia mixture. One child received approximately 5 c.c. of the solution per kilo of body weight, the other between 10 and 15 c.c., the solution being injected slowly over a period of some 50 to 65 minutes. No ill effects were observed. The infant receiving the larger amount of solution developed a slow, deep respiration which persisted for several hours after the administration of the solution. This respiration was not due to acidosis as was shown by laboratory tests."

We call attention to the fact that one of these cases received inadvertently more than twice the usual dose without ill effects.

SUMMARY OF CASES.—All ten of the cases treated by the author (see

TABLE V

SYNOPSIS OF CASES

Case No.	Nature of trauma	Condition immediately before	Dose		Immediate result	Ultimate result
			Amt. c.c.	Rate c.c. / K. / hr.		
I.	Crushed foot.....	S., ? D., 40; P. A., 1.3	0	...	Not treated.....	Died in about 4 hours.*
II.	Gunshot wounds. Hemorrhage	S., 80; D., 70; P. A., 1.5	270	2.2	S., 120; D., 80–85; P. A., 5.5. Circ. seems normal	No retrogression. Discharged well.
III.	Panhysterectomy. Hemorrhage. Infection	S., ? D., 30; temp. 105.6; P. A., 1.0–	200	3.2	S., 80; D., 50; P. A., 2.0+. Slight improvement (?) Temp. 106°	Died in 6 hours†
IV.	Splenectomy. Primary carcinoma of liver. Primary and secondary hemorrhage	S., 100; D., 80; P. A., 2.5–2.8	200	1.9	S., 110; D., 80–85; P. A., 5.0–5.5. "Patient rallied"	Slight recession, then improvement. Next day, S., 120; D., 80. Continuous secondary hemorrhage. Died 4th day
V.	Compound comminuted fractures. Fat embolism (?)	Pressures unobtainable	205	3.0	S., 90; D., 65.....	Died in 10½ hours†
VI.	Intestinal obstruction	S., 90; D., 80; P. A., 1.3	200	2.6	S., ? D., 75–80; P. A., 4.0	Pressures not followed. Died in 10½ hours†
VII.	Cerebral exploration. Hemorrhage	Pulse imperceptible. S., very low; D., 75; P. A., 0.5–3.0	250	4.2	S., 100; D., 78; P. A., 4.0. Circulation much improved	No retrogression. Recovered
VIII.	Kraske operation for carcinoma of rectum. Hemorrhage	S.? D., 58; P. A., 0.3. "Respiration jerky and shallow"	220	2.2	S., 100; D., 78; P. A., 3.5. Circulation much improved	No retrogression. Peritonitis on 4th day. Died on 14th day
IX.	Vaginal resection of cervix. Profuse primary and secondary hemorrhage	Almost pulseless. Pressures undeterminable. P. A., 0+		...	Not treated.....	Died in about 3 hours*
X.	Excision cranial osteoma.* Extreme hemorrhage; transfusion reaction	S.? D., 60; P. A., 0+ Unconscious	300	?	S., 105–110; D., 70–? 80; P. A., 7.5–12.0. Conscious	Circulation normal after periodic falls. Persistent anæmia. Skin infection; died (after transfusion), 22nd day
XI.	Excision dural endothelioma	S.? D., 70; P. A., 1.5	262	4.0	S., 110–115; D., 80–88; P. A., 4.0; circulation improved	Slight, temporary retrogression. Well
XII.	Excision sarcoma, uterus. Hemorrhage	S., 50; D., 45; P. A., 3.5–4.0	210	4.0	S., 105; D., 80; P. A., 10.5. Circulation good	Slight retrogression in pressures, not in P. A. Died 25th day.

Abbreviations: S. = systolic pressure; D. = diastolic pressure; P. A. = maximum oscillation amplitude.
* After being called to hospital.
† Timed from beginning of treatment.

Table V) showed a greater or less immediate improvement in the circulation as a result of the administration of the gum-glucose solution. But in three of the cases (III, V, VI) the improvement was by no means satisfactory at the conclusion of the treatment and did not hold. These cases behaved very much like animals in deep experimental shock, in which the injection temporarily raises the pressure though death is inevitable. Of these three cases, one (III) was a case which undoubtedly was overwhelmed by an infection dating from the operation; the second (V) was a case of compound comminuted fracture of both legs and might have been complicated by fat embolism; while the third (VI) was a case of long-standing intestinal obstruction, which might have been complicated by a general infection, by peritonitis or by toxæmia. All three died within twelve hours after beginning the treatment.

The circulation of Case X was improved much more by the gum-glucose injection than by the blood transfusion, but a considerable fall occurred after the injection of the gum-glucose before the circulation became normal. Subsequently, she had an extreme anæmia and a skin infection to contend with. Death occurred on the twenty-second day after a severe reaction to a blood transfusion. In the remaining cases, six in number (II, IV, VII, VIII, XI, XII), the improvement in the circulation that occurred during the injection held or continued subsequently; they, as well as Case X, recovered from the circulatory disturbance and from shock. The fact that the main improvement occurred during the treatment furnishes presumptive evidence that the latter was the cause of the recovery. A much larger series of cases than we have thus far succeeded in collecting, though, is necessary to prove this beyond peradventure.

Of the seven cases that recovered of shock, or of a condition approximating shock, four died subsequently—Case IV on the fourth day, of secondary hemorrhage; Case VIII on the fourteenth day, of peritonitis; Case X on the twenty-second day, probably of anæmia and skin phlegma, aggravated by a reaction to blood transfusion, and Case XII on the twenty-fifth day of lobar pneumonia and hydronephrosis. These deaths unquestionably were due to causes that were not referable to, or influenced by, the treatment. Seven of the cases (II, III, IV, VII, VIII, X and XII) were complicated by hemorrhage, which, in one case (X), was extreme.*

Two cases that might have received treatment did not; one (Case I) because of an accident to the solution; the other (Case IX) because it was decided that blood transfusion was the preferred treatment, and unavoidable delays resulted in the unfortunate failure to give any intravenous treatment at all. These patients died in about four and three hours, respectively, after I had been called to see them. Although we realize how difficult it is to gauge shock, we feel that the condition of Case I when first seen by us was not any worse than that of some of the cases that received treatment. It is also

* Note.—(At time of proofreading.) We have had another case of marked shock, with very satisfactory results. Up to now (eleventh day) the patient has made normal progress.

difficult to gauge hemorrhage; but we are of the opinion that the condition of the circulation of Case IX, when first seen by us, was no worse than that of our other hemorrhage case (X) at the time the administration of the gum-glucose solution was begun. But however this may be, these are the only cases in our series that we can cite as untreated controls; death occurred earlier in these two cases than in any of the treated cases.

No ill effects of any kind have been noted. During the injection, the circulation always has steadily improved and the anxiety of the patient, when conscious, always has diminished, two of them falling asleep before the close of the injection. With one possible exception (Case VI), there have been no temperature reactions that can reasonably be referred to the injection.

Utilization and Excretion of the Injected Gum Acacia.—Substances similar in composition to gum acacia are widely distributed in the plant kingdom and are very important factors in the nutrition of herbivorous animals, which seem to be able to use 50 to 60 per cent. of the amount ingested. Gum-like substances are, however, a far less important constituent of the diet of man, though those ingested are very largely utilized.[35] Chemically, gum acacia is a pentosan. On hydrolysis it yields a number of sugars of which the pentose, arabinose, is the most important, some samples yielding as much as 50 per cent. of this substance.[36] A certain amount of the ingested pentose always escapes metabolism and appears in the urine in the form of pentose.

We have followed the pentose quantitatively in the urine of Case VIII, using for the purpose the technic described by Testoni.[37] The color produced by this reaction was compared in a colorimeter with the color produced by a standard solution of arabinose treated in exactly the same way. As long as the amount excreted was fairly large the colors could be readily matched; but when the color produced in the urine was faint, it was no longer of the same tint as that of the control, and the readings then became quite inaccurate.

Table VI shows that about 0.7 gm. pentose was excreted in all. Just what this means in terms of gum acacia it is impossible to say. It is obvious, however, that of the 55 gm. gum acacia injected, practically all was utilized. It would also appear that about one-half of the gum injected is taken care of by the organism in the course of twelve hours, but that some of the gum

TABLE VI

EXCRETION OF PENTOSE AFTER INTRAVENOUS INJECTION OF 54 GM. GUM ACACIA

Catheterized sample of	Amount of urine, c.c.	Pentose, gm.
January 21, 3.00 A. M.	170	0.232
January 21, 3.45 P. M.	231*	0.208
January 22, 11.25 A. M.	366	0.079
January 22, 7.20 P. M.	575	0.058
January 23, 4.00 A. M.	500	0.079
January 23, 3.00 P. M.	625	0.035(?)
January 24, 11.00 A. M.	1150	None (?)
Total excreted	....	0.691

* Small amount lost.

remains in the body for over forty-eight hours. These facts should be of some assistance in determining how long the interval between repeated doses of gum should be (see p. 418).

SUMMARY

It is concluded on the basis of the animal experiments of the author and collaborators, and of others, on the mechanism and treatment of shock, that slowing of the circulation in a considerable part, or in the whole, of the body is commonly, if not always, the factor that leads to the development of experimental shock. It is believed that as a result of the slowing of the blood-stream the corpuscles clump in the venules and capillaries which then become choked with solid masses of corpuscles and dilate. The blood flow is thus curtailed still further, indeed, to the point of interfering seriously with the processes of tissue respiration and nutrition. The effective blood-volume is reduced, not alone by the dilatation, but also by transudation of plasma. The organism strives to combat this real and effective reduction in blood-volume by the usual mechanism of pouring tissue fluids into the blood-stream. Largely, if not exclusively, as a result of the deficient general circulation resulting from the reduction in effective blood-volume, the medullary centres, including the vasomotor centres, and the heart, eventually may show some signs of functional insufficiency.

The administration of a combination of hypertonic gum acacia and hypertonic glucose under these circumstances acts beneficially, we believe, in several ways: (*a*) By drawing fluids from the tissues into the blood-stream, thus assisting the normal mechanism in restoring the blood-volume. It is possible that such an *internal transfusion*, as Gesell [5] has suggested calling it, carries from the tissues into the blood-stream a certain amount of proteins and of salts [38, 39] so that the fluid thus added to the blood might resemble much more closely the composition of the plasma than could any artificial solution. (*b*) By maintaining this increased volume through some property of the gum acacia. (*c*) By dilating the arterioles through some specific action of the hypertonic crystalloid.[27] (*d*) By increasing the energy of the heart beat in the same way,[27] and also through direct action of the glucose on the muscle. And (*e*) by augmenting metabolism through the increase in the supply of glucose to the organism between the limits of basal metabolism and self regulation.[40]

There is no need of providing salts with this injection, because the solution is given in relatively small quantity (5 c.c. per kilo of body weight) and very slowly. It can be assumed that it is given so slowly that the salt balance of the blood can be maintained by interchange with the tissues, while the salt balance of the tissues, since the body contains 700 c.c. of fluid per kilo,[41] would not be appreciably affected. The withdrawal of water from the tissues seems to do no harm, probably because of the large supply available; and the loss that does occur can easily and should be made good by the administration of water by mouth, by rectum, and hypodermically.

But even if our views with regard to the cause of the circulatory dis-

turbance of shock should not withstand the test of time, and even if the theoretical reasons for using glucose or gum acacia should prove wrong, there would still remain the empirical tests which show definitely that the gum-glucose solution saves a certain number of animals from death by trauma. The results obtained through the use of the solution in the treatment of shock-like states in man, and after hemorrhage, are not so easily interpreted as are those of the animal experiments. But they show conclusively that the solution is innocuous and they are strongly suggestive, to say the least, of beneficial action.

We here desire to express our thanks to the surgical staffs of the Barnes Hospital and the St. Louis City Hospital, and especially to Dr. Ernest Sachs, Associate Surgeon, acting in charge of the surgical service of the former, and Dr. Ellis Fischer, Associate Surgeon in the Washington University Unit of the latter, who have made this investigation possible by keeping us informed with regard to, and by placing at our disposal, the clinical material suited to our purposes.

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EXPOSURE IN GALL-BLADDER SURGERY

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A review of the literature on the subject of surgery of the gall-bladder makes it self-evident that the members of the medical profession have not all been of the same mind with regard to it. Early discussions all related to the desirability of removing or of merely draining the gall-bladder. This contention is now fairly well settled, and the cases are few in which it is believed that the patient's best interests are served by a simple drainage operation. It must be admitted that cholecystostomy, in the hands of the casual operator, is a much easier and safer operation than cholecystectomy, but no one should attempt to remove gall-stones who is not also able and prepared to do any operation on the biliary tract that may be found necessary. We all know how often complications are found when they are least expected, such as stones in the common duct or even fistula between the gall-bladder and other organs.

Specific indications for the removal of the gall-bladder or for drainage have been thoroughly discussed in medical journals in this country, and the list of indications for removal leaves very little question in the mind of the reader that the right thing to do when in doubt is to remove the organ. The remaining contention, therefore, between surgeons is with regard to the method of removal. A great many believe that removal from the fundus down is the safer procedure, in spite of the fact that the field of operation is more or less soiled with blood during the most important and dangerous part of the operation. I have frequently heard surgeons say that in operating on a thin person with a low-lying liver which is easily rotated into the wound, and with the field of operation practically outside the abdomen, it is a simple matter to remove a gall-bladder by first cutting the cystic duct, but that they would like to see it done in a really difficult case, such as that of an acute gall-bladder in an obese patient with a low costal arch.

My own training has been almost entirely in doing cholecystectomies from below up.[3] I believe that I have had my share of experience in the emergency and acute varieties of cholecystitis with all the added handicaps of obesity and immobile livers, and I am satisfied that with the exposure it is possible to obtain in every case, the rational operation can be safely performed.

To be able to utilize all the exposure possible is, to my mind, an important consideration in surgery. I have never seen a surgeon in trouble while doing a thyroidectomy if he had the maximum amount of exposure, and we can all recall our occasional difficulties when attempts have been made to remove an appendix through a button-hole incision;

FIG. 1.—Inserting pack between liver and diaphragm.

FIG. 2.—Final exposure, showing flattening of visceral surface of liver.

this is also true in operations on the biliary tract. A method that I have used during the past year, which helps in the more difficult cases to visualize the neck of the gall-bladder, the cystic duct and artery, and also their relations to the common duct and the duodenum is as follows:

Technic.—The abdominal incision extends from the midline at the tip of the ensiform to a point about two inches external to the umbilicus. If it is necessary to remove the appendix the incision may be extended downward, especially if there is an excessive amount of subcutaneous tissue. When not contra-indicated the usual exploration is made. The stomach, large bowel, omentum and small intestine, are separated from the field of operation by three or four abdominal sponges, held in place by the left hand of an assistant. It is important when once the sponges are in place that the assistant should not move this hand during the operation. In almost all such cases this exposure is all that is needed, even when the right lobe of the liver cannot be rotated. In the exceptional case, however, additional exposure is obtained by inserting a pack (4 inches by 3 feet) between the posterior-superior surface of the right lobe of the liver and the diaphragm (Fig. 1). In this manner the liver is made to descend slightly, the concave visceral surface is flattened somewhat, and the hilum of the liver is made more accessible. The insertion of this pack is an easy matter and if carefully placed it can in no way injure either the liver or the diaphragm. With an ordinary abdominal retractor the second assistant retracts the right costal margin upward and outward, while with a long shoe-horn retractor the first assistant gently retracts the liver in the opposite direction. The operator is now able to place the pack in position by using a pair of nine-inch tissue forceps, carrying the gauze along the shoe-horn retractor. Fig. 2 shows the final exposure. I have used this procedure in numerous cholecystectomies, and am satisfied that it has frequently made very difficult cases absolutely safe.

Injuries to the hepatic or common ducts, or hemorrhage, are always avoidable if the operator can see what he is doing and if he proceeds carefully. As anomalies of both ducts and blood-vessels are very common, to know the text-book anatomy of this region is not sufficient.[1, 2] Absolute knowledge of what is in each forceps before it is clamped is necessary to safety in the procedure.

In cases of large, tense gall-bladders it is often advisable first to empty the gall-bladder with a trocar, and then to apply a six-inch curved forceps to the fundus and another to the ampulla where it overlies the common duct. By drawing on the forceps, especially the last one, the cystic duct is stretched, and by a little blunt dissection with a pair of seven-inch curved forceps, it may be isolated and exposed throughout its entire length. Before cutting this duct the common duct should be palpated; it is much easier to do this now than later, as it can be steadied by traction on the forceps attached to the ampulla. The cystic duct and the artery are secured separately and ligated with plain catgut; care is taken to

occlude the duct close to its juncture with the common bile duct and not to leave a pouch to be a possible cause of future trouble. If the common duct warrants exploration it is preferable to make the incision sufficiently long rather than attempt investigation through the open end of the cystic duct, which is frequently very unsatisfactory. With the mode of exposure as herein outlined, all these procedures may be safely and quickly executed.

I believe that in the future I shall remove very few gall-bladders by commencing at the fundus. I realize, however, that each case must be judged by itself, and that the steps of an operation should not be decided on until exploration has been completed. In the occasional case it may be difficult to expose the cystic duct and artery. I would then advise commencing the removal at the fundus.

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LONG RESECTIONS OF THE INTESTINE

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Long resections of the intestine are occasionally necessitated by such conditions as extensive gunshot wounds, gangrene and ileocæcal tuberculosis, with multiple strictures. The small bowel varies in length from 15 feet 6 inches to 31 feet 10 inches, the average length being greater in the female. The large intestine varies in length from 3 feet 3 inches to 6 feet 6 inches. People such as the Russian peasantry, who have for generations largely subsisted on a coarse vegetable diet, have longer intestines than those who live on a more concentrated dietary. The removal of the large bowel seems to interfere but little with the bodily nutrition, but after the removal of any considerable length of the small bowel the patient's physiological resources must be very carefully husbanded. Kukula [1] made careful and exhaustive experimental long resections on animals to show by deduction about what proportion of the human intestine could be safely removed.

Both Park [2] and Moynihan [3] have at different times collected all reported cases of long resections of the small bowel, and the total number is not large. It has been rather generally agreed that at least half of the length of the small intestine may be removed, and the patient survives and exists in a fair state of health thereafter. Toombs [4] mentions a case of long resection in which the cæcum and adjacent small bowel were removed. This patient afterward passed through a typical attack of typhoid fever, indicating that Peyer's patches are not necessarily a focus of the disease. After cutting down the length of the small bowel the wastage of fats and albuminous materials in the nutrient must be very great, and this part of the diet must be increased for these cases.

Case I.—Adult, male, aged thirty years, weight, 128 pounds. Referred by Dr. D. G. Preston, Burnwell, W. Va.

General History.—Abdominal pain over a period of eight months. Gradual loss of weight and strength; moderate constipation; no attacks of diarrhœa. Pain beginning in the region of the appendix. Occasional vomiting and considerable regurgitation of food for the past two months. Abdomen slightly rigid, visible peristalsis, some abdominal tenderness. Wassermann negative. White blood count, 6800; pulse, 98; temperature, 99 degrees. Small area of dullness in right upper apex.

Diagnosis.—Ileocæcal tuberculosis causing partial obstruction of small bowel.

Operation.—Assisted by Dr. B. S. Preston and Dr. Atlee Mairs,

the following operation was performed January 4, 1916: Right rectus incision about 20 cm. in length. The cæcum was an enlarged mass about the size of a grapefruit. Numerous (eight) tubercular strictures of the small bowel were noted. To eliminate these it was necessary to resort to the radical operation as advocated by Caird [5] and resect 300 cm. (10 feet) of the small bowel as well as the cæcum and 20 cm. (8 inches) of the ascending colon. A lateral anastomosis was made to the transverse colon. Patient reacted fairly well, but vomiting was quite persistent. Thirty-six hours after the operation it was deemed advisable to reopen the abdomen for the relief of obstruction. Some milky fluid was noted in the right flank. Some of the peritoneal sutures of fine silk had failed to hold. All such points were reinforced with additional silk sutures. A slightly adherent kink was noted in the small bowel, near its junction with the colon. This was straightened out and the contents of the rather distended small bowel were milked into the colon. Two medium-sized rubber cigarette drains were inserted in the wound. In exactly twenty-four hours the patient vomited again, this time a distinctly dark brown vomit. Under novocain-suprarenin anæsthesia an incision was made in the left rectus, a distended loop of small bowel was drawn out and a medium-sized soft-rubber catheter was purse-stringed into this, after the method of Dr. J. W. Long, and brought out through the upper angle of the wound. Bowel contents drained from the tube quite freely. The patient did not vomit again. The tube came away the eighth day. The discharge from the fistula caused some skin excoriation, but the sinus closed in two weeks. After this the patient made an uneventful recovery, and at the end of the fourth week left the hospital by his own request, with his wounds entirely healed. A few days after the operation his bowels began to move, and at first he had an average of six bowel movements every twenty-four hours. This condition gradually improved, and by the time he left the hospital he was having an average number of three movements in twenty-four hours.

After his recovery and discharge from the hospital this patient was exhibited before the Kanawha Medical Society.

X-ray examination by Dr. W. R. Hughey shows a rapid filling of the very limited small bowel, with early entry into the transverse colon, part of the contents regurgitating into the remains of the ascending colon and hepatic flexure.

Later History.—This patient left the city in severe winter weather and visited friends in the mining regions near by. During this time he celebrated by getting drunk. A few days later he returned to Charleston, suffering from a very severe cold. He rapidly became worse and developed the symptoms of an acute tuberculosis of the lungs. He reëntered the hospital February 23, 1916, and on February 28, 1916, died.

Postmortem examination made by Drs. M. I. Mendeloff, H. D. Hatfield and the writer. The abdomen was opened by a long, median incision. With the exception of a few adhesions in the location of the former drainage tubes, the intestines were in excellent condition. The anastomosis was as smooth as if it had existed for years. There were no visible signs of visceral tuberculosis. The few palpable mesenteric glands that were present at the time of the original operation had disappeared. The small intestine up to the duodenojejunal junction was measured and found to be only 5 feet 7 inches in length. Of the large bowel there were 4 feet 9 inches.

Fantino [6] suggests that in cases of extensive resection a vicious circle should be established in the remaining segment of bowel in order that the intestinal contents may circulate long enough to complete the digestive and assimilative processes.

Turck [7] says: "A review of the literature and a study of case histories point plainly to the fact that, from a viewpoint of ultimate results, short-circuiting, whenever possible, is much to be preferred to resection, particularly if the lower ileum is involved. In the case reported above, while circuiting was decided against at the time of operation because of the indescribable adhesions, the foul sinuses and fistulous tracts, it is probable that a better ultimate result would have been attained had the worst segments been removed, and the remaining adherent gut short-circuited in one or two places. This patient certainly has not enough small intestine to permit of thorough absorption, though compensatory intestinal hyperplasia provided adequate digestion."

Henson [8] in his report on Turck's case says that with the usual hospital diet the patient had about six stools per day. He was then given astringent and digestive ferments, but these had no effect whatever on the number of stools.

Henson's summary is so complete that it is quoted along with his tables.

The following table shows the average number of stools per diem under a variety of restricted diets:

Special Diet	Average Number of Stools per Diem
Chicken, roast beef, toast and cereals	5.00
Oatmeal, sugar and milk	4.25
Irish potatoes, oatmeal, sugar and milk	4.00
Regular hospital diet excluding all meats	3.66
Hospital soft diet	3.00

"The fæces were examined after having been on the regular hospital diet for several days, resulting in the following findings:

"Stool, fluid; quantity, 700 grams; color, light yellow; odor, not especially offensive. Reaction, acid to both litmus and phenolphthalein. Chemical tests for starch,

erythrodextin, sugar, and occult blood were all negative; for mucin, only slightly positive.

The stool macroscopically showed a moderate lientery, which, upon microscopic examination, was found to be due to an azotorrhea. The fibers were mostly digested to the point that the transverse striations and nuclei were not shown, but in some both longitudinal and transverse striations could be observed. Steatorrhea not present, nor were crystals of any form in excess.

"The patient was then placed upon the following diet:

	Grams.	Albumin per cent.	Fat per cent.	Hydrates per cent.	Calories
Zwieback	100.00	8.00	1.00	75.00	349.60
Toast	200.00	14.00	1.00	110.00	517.70
Potatoes	192.00	2.60	.....	38.40	168.10
Eggs (4)	.....	28.20	22.00	.....	320.92
Butter	30.00	.....	23.00	.....	214.66
Cream	128.00	4.62	34.24	4.50	356.96
Milk	256.00	8.96	6.40	9.98	137.37
Sugar	40.00	.14	.....	37.33	164.00
	946.00	66.52	87.64	275.21	2,229.31

"Weight of patient, 63 kilos; 35 grams to kilo equals 2205, equals required calories at rest.

"It is worthy of note that during all preceding periods in which his urine was examined for indican this constituent was constantly and markedly in excess, but that two days after being on the foregoing diet the indicanuria almost entirely disappeared. While on the diet tabulated his average urinary output was 456 c.c. per diem, the specific gravity of a twenty-four-hour specimen was 10.28, the total urea output in the twenty-four hours was 7.84 grams. His stools following the use of this diet averaged three per diem. The fæces within a short time became semiformed with an average weight of 755.2 grams. There were no chemical or microscopic findings different from what has already been recorded while the patient was on the regular diet, with the exception, of course, that the azotorrhœa was not present. Further tests for starch, erythrodextrin and sugar were all negative.

"In this case it would seem probable that a compensatory hyperplasia of the small intestine and a compensatory production of the ferment enterokinase was at least commenced. We know that amylopsin and steapsin are capable of exercising their functions with little auxiliary aid from this ferment. It is reasonable, therefore, to presume that the compensatory production of enterokinase in this patient has reached the point where, together with the enzymes of the pancreatic juice, it is sufficient to digest pretty thoroughly the intake of carbohydrates and fats, but that this compensatory production has not reached the point of thoroughly digesting proteids.

"For the purpose of demonstrating to what extent the absorbability of the intestine is interfered with, Sahli's method was tried, the patient being given 0.15 gram iodoform in a salol-coated gelatin capsule with an Ewald test meal. The appearance of the iodin reaction in the saliva on two different occasions was delayed six hours, hourly tests being conducted."

I append a table of cases taken in part from Park, Moynihan and other sources, and relatively taken up to date.

TABLE OF REPORTED CASES OF LONG RESECTION OF INTESTINE

Operator and reference	Length of section of intestine resected	Result
Schlatter: Kor.-Bl. f. Schweiz, Aerzte, 1899; Beiträge z. klin. Chir., 1906, xlix, i; Lancet, 1900, i, 207	192 cm. after "considerable shrinking" subsequent to removal.	Recovery
Boeckel I: Bull. de l'Acad. de med., Paris, 1912, lxviii, 241	200 cm.	Recovery
Lexer: Berl. klin. Wchnschr. 1900, xxxvii, 4; Albu: Berl. klin. Wchnschr., 1901, No. 50	200 cm. small intestine.	Recovery
Peterson: Ref. Rusch-haupt., Inaug. Diss., Bonn, 1901	202 cm.	Recovery
Flint, J. M.: Johns Hopkins Hosp. Bull., 1912, xxiii, 127	204 cm. collapsed	Death six days later
Reder, Francis: Personal communication.	204 cm. ileum	Recovery
Koeberle: Centralbl. f. Chir., 1881, viii, 249	205 cm. small intestine	Recovery
Myaki: Arch. f. klin. Chir., 1910, xciii, 708	206 cm. resected	Death 4 days later of septic peritonitis
Enderlin; Ref. Lauenstein: Deutsche Ztschr. f. Chir., 1909, c, 169	207 cm. resected	Recovery
Kocher, quoted by Trzebicky: Arch. f. klin. Chir., 1894, xlviii	208 cm. small intestine	Recovery
Mikulicz: Rothe, Beiträge z. klin. Chir., 1902, xxxiii, 140	215 cm.	Recovery
Dreesmann: Berl. klin. Wchnschr., 1899, xxxvi, 337	215 cm. ileum	Recovery
Axhausen: Mitth. a. d. Grenzgeb. d. u. Chir., 1909, xxi, 55	215 cm.	Recovery
Karlow: Hygeia, No. 3	215 cm. small intestine	Recovery
Thon: Deutsche med. Wchnschr., 1909, xxxv, 742	220 cm.	Recovery
Dekonski: Ref. Istomin: Russ. med. Rundschau, 1910, viii, 329	220 cm.	Recovery
Kouwer: Nederl. Tijschr. v. Geneesk., Amst. 1898, 2 R., xxxiv, d. 2, 887	224 cm.	Recovery
Shepherd: Centralbl. f. Chir., 1898, xxv, 397	234 cm. ileum	Recovery
Kukula: Arch. f. klin. Chir., 1900, lx, 887	237 cm. ileum	Recovery
Harris: New York Med. Rec., 1902, lxii, 566	239 cm. ileum	Recovery
Kirkwood, W. L.: Medical Journal of Australia, 1915, ii, 49	240 cm. resected	Recovery; abscess; second operation for recurrence of symptoms 9 mos. later. Recovered; well and better than after first
Hayes, quoted by Harris	248 cm. small intestine	Recovery
Brenner and Denk: Wien. klin. Wchschr., 1907, xx, 1649	250 cm.	Recovery
Enochin: Red. Istomin, Russ. med. Rundschau, 1910, viii, 329	250 cm.	Recovery
Peck, quoted by Harris	251 cm. small intestine	Recovery
Blayney: British Med. Jour., 1901, ii, 1456	255 cm.	Recovery
Lauwers: Ann. de la Soc. de Chir. (de Belge), 1901, ix	265 cm. small	Recovery
Park: Arch. Onter, de Chir. i, Centralbl. f. Chir., 1904, xxxi, 55; Buffalo Med. Jour., 1903	265 cm. small	Recovery
Payr: Arch. f. klin. Chir., 1902, lxvii,181	265 cm. ileum	Recovery
Pokotilo: Chirurgia, 1909, xxv, 169	270 cm. resected	Recovery

Operator and reference	Length of section of intestine resected	Result
Mitchell: quoted in Kelly and Noble's Abdominal Surgery, Philadelphia, 1908, p. 442	274 cm.	Death
Kopfstein: Revue de Bohm. Med., 1909, Ref. Wien. Med. Bl., 1910	275 cm.	Recovery
Maydi: quoted by Kukula; Arch. f. klin. Chir.	284 cm. ileum and 8 cm. colon	Recovery
Childe: British Med. Jour., 1901, ii, 891; Practitioner, 1909, cxxxii, 364	289 cm.	Recovered; lived seven months
Lorenz: Wien. klin. Wchnschr., 1906, xix, 610	292 cm.	Recovery
Goebell: Deutsch. Ztschr. f. Chir., 1905, lxx, 608	300 cm. small intestine	Recovery
Fantino: Riforma med., Naples, 1902, xviii, 181	300 cm.	Death one month after operation
Tombs, quoted by Murphy; Year Book General Surgery, 1915	305 cm.	Recovery
E. Stachlin: Annals of Surgery, 1907, xiv, 49, and personal communication	305 cm.	Recovery
Fantino: Gaz. medica di Torino, 1896, xlviii	310 cm. ileum	Recovery
Monprofit: Rev. di Chir., 1899, xx, 579	310 cm. intestine (230 cm. ileum; 80 cm. large intestine)	Recovery
Ghedini: Clin. Chir., Milano, 1905, xii, 278	315 cm.	Recovered, lived three and one-half months
Zusch: Deutsch med. Wchnschr., 1909, p. 739 (operation in 1896)	316 cm.	Recovery
Fischer, A.: Orvosi hetil, No. 37, 1905; Centralbl. f. d. Grenzgeb. d. Med. u. Chir., 1906, ix, 70	316 cm.	Recovery
Zeidler: Centralbl. f. Chir., 1906	318 cm. ileum	Recovery
Whitall: ANNALS OF SURGERY, 1911, civ. 699; ANNALS OF SURG., 1913, lviii, No. 5	320 cm.	Recovery
Norton: Ref. Kelly and Noble, Abdominal Surgery, Philadelphia, 1908, p. 442	322 cm.	Recovery
Myaki: quoted by Flint; Johns Hopkins Hosp. Bull., May 1912	328 cm., ileum; 225; colon, 13	Recovery
Ruggi: Policlinico, 1896; Centralbl. f. Chir., 1896, xxiii, 365	330 cm. principally ileum	Recovery
McGuire: Surg. Gynec., and Obst., January, 1913	336 cm.	Recovery
F. J. Brougham: Surg., Gynec. and Obst., v. 782	345 cm.	Recovery
Nicola: Clin. Chir., 1910	350 cm.	Recovery
Baracz: Arch. f. klin. Chir., lxxxiii, 478	350 cm.	Death two days after operation
Von Eiselsberg (the case is given by Park, Payr and others, but I can get no further particulars)	350 cm.	Death after twenty-five days
J. W. Long: personal communication	360 cm. ileum	Death
Obalinski: Arch. f. klin. Chir., 1894, xlviii, 16	365 cm. ileum and cæcum	Death in twenty-eight hours
A. Werelius: Jour. Am. Med. Assn., 1907, xlviii, 945	12 feet, 2 inches (365 cm.)	Recovery; button passed on tenth day
Mitchell: British Med. Jour., 1902, ii, 975	366 cm.	Recovery
Turck: New York Med. Jour., 1914, xcix, p. 316	371 cm. ileum and colon	Recovery
W. D. Haggard: Personal communication	380 cm. ileum and cæcum	Death in eleven days
Pauchet: Personal communication; Jahresbericht f. Chir., 1905, xi, 732	400 cm. ileum	Recovery
Friedrich: Med. Klin., 1904–05, i, 25]	400 cm.	Recovery

Operator and reference	Length of section of intestine resected	Result
Stolz: Deutsch. med. Wchnschr., 1909, p. 744	475 cm.	Recovery
Axhausen: Mitt. a. d. Grenzgeb. d. Med. u. Chir., 1909, xxi, 55	475 cm.	Recovery
Storp: Deutsch. Ztschr. f. Chir., 1907, lxxxvii, 322	510 cm. small intestine (the entire ileum and part of the jejunum)	Recovery
Nigrisoli: Atti del. xvi Congr. Ital. de Chir., 1902	520 cm. small intestine	Recovery
Ghedini: Clin. Chir., Milano, 1905, xiii, 278	524 cm.	Recovery
Brenner, reported by Denk: Mitth. a. d. Grenzgeb. d. Med. u. Chir., 1910, Heft i. p. 146	540 cm.	Recovery

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LOTHEISEN'S OPERATION FOR FEMORAL HERNIA*

By Hermann Fischer, M.D.
of New York

Looking over the literature of operations for inguinal and femoral herniæ the student is struck by the fact that there is almost a complete unanimity among surgeons as to the proper procedure in dealing with an inguinal hernia. Bassini's operation has become the common property of surgeons all over the world; all other methods have been practically abandoned. In the treatment of femoral hernia this happy situation does not obtain. A large number of different methods (over 70) have been invented and advocated from the simple Bassini to the complicated bone-periosteal flap plastics of Trendelenburg and Kraske. The multiplicity of methods alone shows that the problem has not been solved satisfactorily. Although experienced surgeons proclaim that simple closure by suture of the external femoral ring is sufficient, it is a fact that a number of femoral hernias thus operated upon recur early, especially those of large size.

I shall not go into detail as to the different methods proposed. It is sufficient to state that all of the older methods which attacked the problem from the crural side have failed to take into consideration the fundamental anatomical principle involved, *i.e.*, closure of the *internal crural ring by a muscle-fascia plastic*.

Some years ago a number of authors chose the inguinal route for the operation of crural hernias (Annandale, 1876; Ruggi, 1898; Parlavecchio, Edebohls, Narath). Tuffier, Lotheisen and Foederl have independently of each other advocated this route and have tried to make it popular among surgeons. Among American surgeons it was Kammerer who introduced the inguinal route here, availing himself of the Lotheisen method (1904). In 1907 Moschcowitz published his operation, having used his method first in 1905. The same procedure has been described and highly advocated by Frank in 1909. I personally became acquainted with Lotheisen's operation in 1904, having assisted Doctor Kammerer in a number of cases. I was so favorably impressed by the operation that it has become my method of choice in all cases of femoral hernia that present themselves.

The operation is executed as follows: Skin incision along Poupart's ligament about one-quarter inch above the same, beginning at the pubic spine and ending one-quarter inch within the anterior superior spine of the ilium. Division of the fascia of the external oblique muscle, which is retracted until the border of the conjoint tendon and internal oblique muscle are exposed. The spermatic cord, or the ligamentum rotundum, is

* Read before the New York Surgical Society, April 9, 1919.

pulled upward and inward by a small blunt retractor; sometimes the round ligament is small and atrophic and can be ignored. The posterior wall of the inguinal canal consisting of the aponeurosis of the transversalis muscle and transverse fascia is now incised, not near Poupart's ligament, but about one-quarter inch above it. We have now reached the properitoneal space; a few small veins, branches of the epigastric, have to be tied. The next step is to clear away the loose areolar and fatty tissue which overlies the neck of the sac and the femoral vein in order to identify these structures. I make it a point to identify the femoral vein first, which is invariably easily accomplished. The neck of the sac is then found lying close to the inner side of the femoral vein. This latter structure is carefully pulled outward by a blunt retractor. If the sac is small and does not contain omentum or intestines which are adherent, it can easily be pulled out of the femoral canal.

Thus, the femoral hernia has been transformed into an inguinal one. If the sac is large, containing omentum and intestines which are not reducible, I open the sac, reduce its contents and pull the sac out of its bed.

The next step is to identify Cooper's ligament, which is easily done by retracting the conjoined tendon and the properitoneal tissue upward and removing with a gauze sponge the thin areolar tissue covering the pectineus muscle. The ligament will be seen as a white glistening band, covering the ilio-pectineal line. Chromic gut sutures are now put through the muscle shelf and through Cooper's ligament, two or three sutures being usually sufficient. The needles must be small and must have a full curve. Care has to be taken in putting the last suture which comes to lie close to the femoral vein in order not to injure the vessel. The sutures are tied, and thus the crural canal will be shut off close to the femoral vein. Suture of the fascia of the external oblique and skin finishes the operation. After having united the cut in the external oblique fascia, it will be noticed that there exists a small funnel-shaped dead space between it and the sutured muscle. This can easily be obliterated by a good fitting spica exerting a little compression at this point.

In large and strangulated femoral hernias I change my skin incision a little by giving it a downward sweep over the highest point of the tumor below Poupart's ligament and dissecting the skin flap upward. The constricting fibres of Poupart's ligament are then divided from above downward under complete guidance of the eye and with certain avoidance of accidents to anomalous vessels or to the incarcerated contents of the sac. The incised Poupart's ligament is reconstructed by two chromic sutures.

In these cases of *strangulated* femoral hernia in which Poupart's ligament has to be sacrificed, the advantages of Lotheisen's operation over the Moschcowitz-Frank method becomes especially apparent. In the latter method the cut ligament has to be utilized for the plastic closure, and has therefore to bear the pressure of the abdominal contents, whereas

in the Lotheisen operation the strain is entirely transferred from Poupart's ligament to Cooper's ligament. The latter fact can be demonstrated by examining patients after operation in the erect posture. If the patient is made to strain or cough, it will be seen that there is a distinct inward and upward pull of the abdominal muscles above Poupart's ligament, instead of a bulging outward.

I have operated upon thirty-seven cases. Of these twenty-two have been reëxamined. Five cases have been reëxamined after three years, seven cases after five years, three cases after six years, one case after eight years, one case after nine years, five cases after four to five months. None of these patients showed a recurrence.

TRANSPLANTATION OF THE VERMIFORM APPENDIX INTO THE FEMALE BLADDER TO SUPPLY AN ABSENT URETHRA*

By Charles M. Rosser, M.D.
of Dallas, Tex.

The vermiform appendix has had medical and surgical consideration for disorders consequent to its pathological changes for many years, but few attempts have been made for its utilization and fewer in which practical benefit has been derived. The case I am to report does not, of course, answer seriously the question often proposed by the laity, *i.e.*, "what is the appendix for?" but it is of somewhat unique significance that it may be successfully transplanted for a practical purpose.

In the operation I report I was able to employ principles already worked out for the cure of a condition heretofore baffling to the surgeon, of intolerable annoyance to the patient, and in doing so hope to have opened the way to a more successful method of dealing with hypo- and epispadias.

The appendix has been brought through the abdominal wall for drainage and irrigation results, but in this no excision was required. It has been brought down and attached to the uterine cornu to substitute an ablated tube. Dr. Robt. T. Morris has succeeded in such a transplantation both by previous and later cecal severance.

In my case a free transplant of the appendix was made within a prepared tunnel extending from slightly within the neck of the bladder to a point near the clitoris where the normal meatus had been before its destruction.

In October, 1918, Mrs. A. presented herself in my clinic at the Baptist Sanitarium with the following pertinent history. Widow, aged forty-eight, no important clinical conditions except that, for what she had been told was a malignant tumor of the urethra, that organ had been removed at the bladder juncture five years previously. Since that time the bladder was both minus a delivery tube and the power of urinary control. Scar tissue consequent to ancient surgery preceded plastic quilling of the anterior vaginal lining, and a tunnel behind it would certainly ulcerate from urinary travel if passing through, and there was no promise of preventing closure except by an insert of some variety of tissue lining tolerant to frequent contact with kidney excretion.

The appendix seemed to offer only autogenous material meeting both architectural and histological requirements. The operation planned and executed consisted of incisions through the mucosa, one

* Read before the Southern Surgical Association at its annual meeting, Baltimore, December, 1918.

below the clitoris, and the other at the bladder exit between which a tunnel behind the anterior vaginal vault was made with suitable forceps. Mucosa was dissected from inside neck of the bladder for the distance of about three-fourths of an inch. Splitting the mucous membrane over the neck of the bladder longitudinally uncovered the remaining portion of its sphincter so that it could later be narrowed.

These preparatory steps taken, the patient's normal appendix was removed together with its meso and quickly placed in warm saline. While held emersed in this the tip was cut off, its lumen sterilized by injection of 50 per cent. alcohol, and a small-sized catheter passed through it. The meso-appendix was then clipped and several linear incisions made through the peritoneal coat. So prepared, the catheter with the transplant was inserted through the tunnel described well into the bladder, the distal end of the appendix entering the freshened bladder neck about one-half inch, where it was sutured as was the tunnel to bladder with fine catgut. The proximal end projected fortunately half an inch out of the upper end of the tunnel. This made a meatus possible by splitting and sewing the flaps back on either side to a denuded surface. I should add that while suturing the bladder neck to the prepared and transversed tunnel care was taken to restore sphincter action by suturing such neglected fibres as could be found, and that the juncture line was reinforced by pedunculated flaps dissected for that purpose.

For four days the catheter was allowed to remain, the only treatment being daily irrigations with warm boric solution. A protecting silk stitch was then cut, the catheter withdrawn, and the bladder irrigated through the new urethra. The catheter was then replaced for a few days, after which its use was discontinued.

The patient left the hospital in ten days but was under constant observation for several weeks, during which time the bladder behavior was normal, control being perfect, the capacity which had been greatly lessened by the five years of incontinence gradually expanded, and the transplanted appendix accustomed itself to its new surroundings, furnishing what promises to be a permanent and satisfactory urinary canal.

TREATMENT OF STREPTOCOCCUS SEPTICÆMIA COMPLICATED BY WOUND DIPHTHERIA, MAKING USE OF TRANSFUSION OF BLOOD IMMUNE TO THE STREPTOCOCCUS

By Chas. S. Vivian, M.D.
of Humboldt, Arizona

Chief among the causes of failure in combating streptococcus septicæmia, by means of the intravenous introduction of antistreptococcic serums, is in all probability the fact that the serum used does not contain specific antibodies for the particular strain of streptococci which is at fault. Being confronted with a severe case of this nature and having this hypothesis in mind, it occurred to me, that the best weapon to use against the streptococcus would be the serum or blood in which antibodies had been produced by vaccination with the organism recovered from the patient's blood stream. Since transfusion of blood by the citrate method is always possible and a vaccine is easily made, it remains only to find a suitable donor. The following case illustrates the scheme of treatment practiced at the Humboldt Hospital:

The patient, a boy of sixteen, always previously healthy, stumbled and fell, while walking along a dirt road in the southern part of this State. He received a laceration of the soft parts of his right thigh about three inches above the knee. This laceration was sewed up and a plaster case was applied to the leg above, including and below the knee. Two days subsequently his temperature rose to 104° F., and continued to reach this point or above for ten days following. He was then taken to California, where an X-ray disclosed the presence of a dog bone, sewed up in the soft parts close to the femur. This was removed and several counter-openings were made to allow for the escape of pus. Notwithstanding that there was free drainage, the temperature continued to rise above 104° F. daily. This continued for two weeks, at the end of which time he was brought to Humboldt, and placed under the care of the writer. Temperature upon admission 103° F. at 4.30 P.M. Smears taken from the wound upon admission on July 5, 1918, showed the presence of streptococci in short chains. The urine contained a rare cellular cast, albumen, red and white cells and the streptococcus. There was no heart murumr. Dakin's fluid was led into the numerous wounds around the knee by means of Carrel tubes and several subcutaneous accumulations of pus were evacuated. He was given 170 c.c. of antistreptococcus serum subcutaneously over a period of about five days, with no effect on the temperature. The knee on July seventh was reported as negative for pus by an X-ray consultant. Blood cultures grew short chained streptococci from which vaccine was prepared on July tenth. A suitable donor, one of the

nurses who volunteered, was given a small dose of vaccine on the tenth, a slightly larger one on the eleventh, and one hundred million organisms on the twelfth, after blood had been taken for transfusion. One hundred cubic centimetres of her blood was given by the citrate method intravenously to the patient. She received two hundred million organisms on the thirteenth, and her blood sent to the laboratory two days subsequently was reported as being strongly antistreptococcic by titration in high dilution. Each dose of vaccine had produced a sharp reaction in the donor. There was no reaction in the patient following the transfusion, until which time his temperature had continued to range between 104° F. and 104.6° F. in the afternoons, swinging down to nearly normal in the mornings. The pulse previous to this time had reached 130 and a mitral murmur had developed. The day after the transfusion, the temperature did not go above 102.5° F., although the pulse remained fast. The next day, however, the temperature was again 104.5° F., which point it continued to reach until the sixteenth, when another transfusion of immune blood was given. More than 100 c.c. were drawn, the intention being to give at least 300 c.c., but it showed a marked tendency to clot, although the same strength citrate solution was used, *viz.*, 2.90 per cent. The clot was filtered out and the resulting 100 c.c. was all that was given. The transfusion produced an immediate violent reaction, marked by a rigor of forty minutes' duration, followed by a drop in temperature to 96° F. During the next few days the whole picture changed. The patient no longer had the appearance of being desperately ill, his appetite returned, and bed sores which had developed, despite the most scrupulous care, began to take on a more healthy aspect. Blood culture taken on the nineteenth failed to grow the streptococcus and streptococci which had been constantly present in the urine were absent. The ankle-joint, which had previously been swollen, gradually subsided. The temperature was markedly lower, although it still went as high as 102.5° F. and once went above 103° F.

On the tenth of July smears from the wounds showed the presence of the diphtheria bacillus, secured by raising from the incised areas the dirty, gray membrane, which bled upon removal.

Five thousand units of diphtheria antitoxin were given on the tenth, followed by a like amount upon the eleventh. Three thousand units were given on the twelfth, and, after the stock had been replenished, twenty-five thousand were given on the fourteenth, twenty-four thousand on the fifteenth and and twenty-seven thousand on the sixteenth. On the seventeenth twenty-seven thousand units were given, to be followed on the eighteenth by forty-nine thousand units, which concluded the treatment with antitoxin, as culture from the wound had failed to grow the Klebs-Loeffler bacillus. All diphtheria antitoxin was given subcutaneously. The continuation of temperature around 102° F. after both infecting organisms were apparently eliminated seemed to call for more radical drainage to eliminate the pus producing bacteria which were still present in the smears. The question of amputation was raised at

this time, but it was thought better to delay this measure because of the attendant shock. On the twentieth, under ether, the wounds which were still draining were laid open, and the cavity of the knee-joint was drained by a circular incision which divided all the structures down to the popliteal space. A small amount of pus was seen to drain from a rent in the capsule of the knee-joint and the joint surfaces themselves were found eroded as from arthritis. The leg was flexed on the thigh and a rubber tube was placed in the cavity of the knee, to be replaced by a Carrel tube the next day. The drainage operation had little effect upon the temperature, which continued to rise daily above 102° F. until the twenty-ninth when it gradually fell below 102° F., above which point it was never again recorded.

Blood transfusion was again done on the thirtieth, using this time the boy's sister, who had not been immunized to the streptococcus as donor. There was no reaction but the hæmoglobin rose from 70 per cent. to 80 per cent. Convalescence was very protracted because of the bed sores and because of aseptic thrombosis of the external saphenous vein below the knee which sloughed to the bone. The boy left the hospital on crutches on the first of April, 1919, having a stiff knee and one or two areas still uncovered by skin.

CONCLUSION

Failure to find the streptococcus where it had been previously (*i.e.*, in the urine and blood) after the second transfusion is presumptive evidence that the immune blood had a curative effect.

DOUBLE-EYED ANEURISM NEEDLE

By Angelo L. Soresi, M.D.

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at present serving in the Italian army, as surgeon at the Ospedale Militare Principale, Milano

All surgeons have experienced considerable inconvenience when using the common one-eyed aneurism needle, when a double ligature is necessary and the thread has to be divided: the surgeon and the assistant might take and pull the wrong end of the thread which gets twisted and a great deal of time, and temper, is lost in untwisting it.

We will not dwell too long on these inconveniences, as they are too well known to all surgeons, but would like to point out the advantages

Fig. 1

Fig. 2

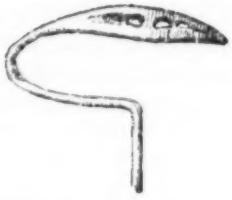
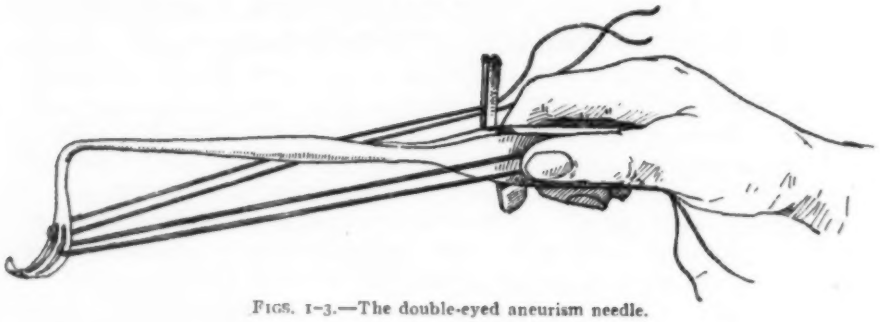


Fig. 3



Figs. 1–3.—The double-eyed aneurism needle.

of the two-eyed aneurism needle, that we have devised, which are the following:

The two-eyed aneurism needle is exactly the same as the single-eyed one commonly used, and can be made to any pattern the surgeon may wish, the only difference between them being that the needle commonly known has one eye, and the one we wish to bring before the surgeon has two eyes, which eyes can be placed one over the other, or side by side, as shown in the illustration (Figs. 1 and 2).

The double-eyed aneurism needle we show in the illustration has a small spring catch on the handle, which, as explained later, facilitates the work of the surgeon, but that is not indispensable.

The method of using the double-eyed aneurism needle is to thread through the outside or the upper hole, a thread about 15 cm. long, the ends of which should be caught in the spring catch placed on the handle. Another thread of about equal length is threaded through the other hole and the surgeon should hold the second thread with his thumb, as shown in the illustration (Fig. 3). After the needle has been passed through the

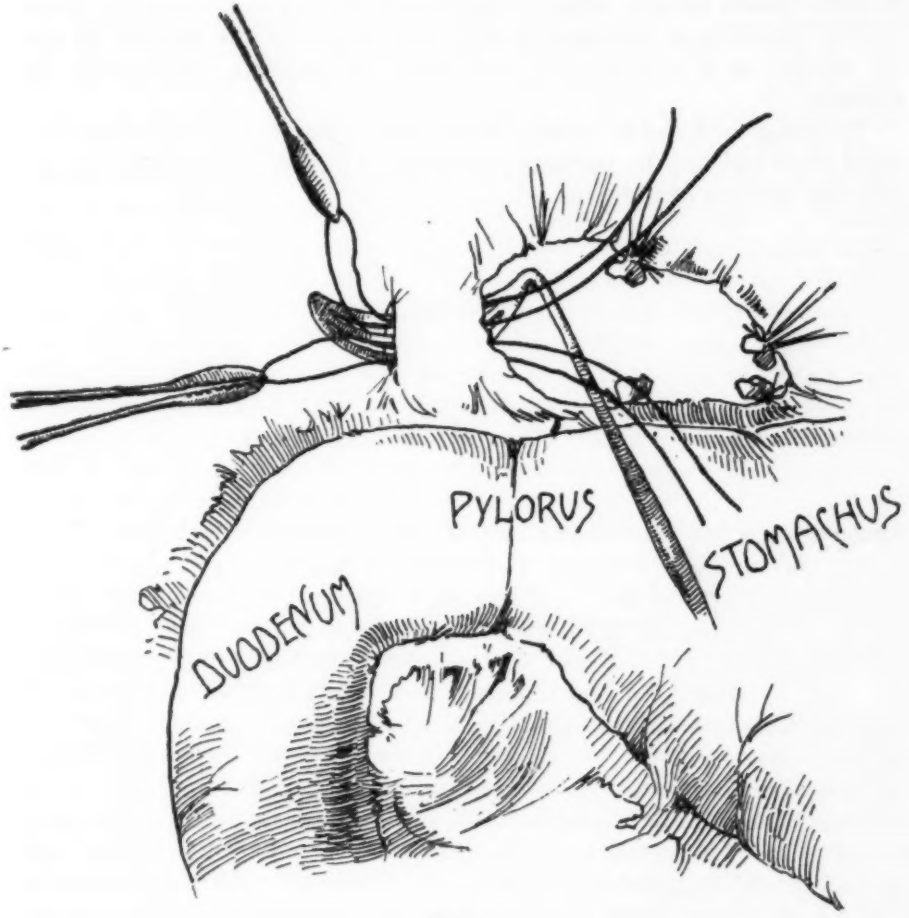


FIG. 4

tissues to be divided, the surgeon should take hold of either one of the threads with a forceps, the assistant taking hold of the other, and then pulling back the needle. In this way, there is no possibility of making a mistake by twisting the threads, and the ligation of any tissue that has to be divided between two ligatures is made easily and rapidly (Fig. 4).

We would suggest that the surgeon should use threads of different colors and qualities, as we always do, particularly in cases of resection of

the stomach. While dividing the mesos, linen thread is used on the portion that will be resected, and catgut is used on the ligatures that will remain in the abdomen.

With the double-eyed aneurism needle, ligatures and divisions of tissues are rendered more easy and rapid: they are much more rapid than when the single common-eyed aneurism needle is used, because the surgeon has not even the trouble of dividing the thread, which division at times causes trouble, because one end of the thread remains too short.

The double-eyed aneurism needle does not cause the surgeon to lose his temper, as is so often the case when, for instance, the threads get twisted.

Working with the aneurism needle mentioned above is rendered even more rapid and easy by threading each eye of the needle with threads of a different kind or of different colors.

BOOK REVIEWS

THE EARLY TREATMENT OF WAR WOUNDS. By Col. H. M. W. GRAY, Late Consultant Surgeon British Expeditionary Force, France. London. Oxford University Press, 1919. Octavo; cloth; pages, 299.

This little book is now chiefly of historical interest. At the time when it was compiled, in August, 1918, the most active phases of the International war were being wrought out and the demands for surgical effort under the peculiar conditions of military activities were incessant and important, and no one at that time was optimistic enough to indulge the thought that the collapse of the German power was so near at hand. The foreword by Lieutenant-General Goodwin, Director of the Army Medical Service, bears the date of September 9, 1918, and in his contribution to the book the General emphasizes the immense assistance which such a book should give to the Army Surgeon, evidently under the full impression that for an indefinite time yet the demand for the application of its teachings would still be called for. The morning of November 11 put an end at once to the extraordinary conditions which gave importance to such a book. We accept it now, however, as a clear and interesting record of the conditions and methods of the military surgery of that war. The book belongs to the same class as that of Hull on the Surgery of War which has recently been the subject of a review in the ANNALS.

The author aptly remarks in his preface that the late war was the young man's war in surgery as well as in purely military matters, since mental and bodily activity counted for much in the ability to meet the demands which the progress of events were continually making upon the endurance and the responsiveness of those who were to do its work. The demand was for young surgeons of fresh and active brains and dexterous hands.

The author says that it was a great privilege and honor to work with the medical officers of that army whose keenness and efficiency were inspiring and whose thoughtfulness and courtesy afforded constant encouragement. Alike with others who were familiar with the conditions of medical relief on that field of strife, he does not fail to give high honor to those assistants of humbler rank who contributed so large a share in bringing about the happy results which were secured. He says, "The stretcher-bearer on the field is one of the heroic figures of the war." None will gainsay the truth of his statement that medical officers who have not experienced the stress, anxiety and limitations of the work near the front during severe fighting can appreciate the problems and the necessities of the work which had to be done under such surroundings. Surgeons in advanced units, even in quiet times, only approach the ideal which it is possible to attain in more permanent surroundings. The particular method adopted by a medical officer at the front in any given case must be determined by the conditions on the spot, the facilities

at hand, the number of cases that come in, and the circumstances affecting evacuation.

It is in such a state of mental toleration and judgment that the general surgeon is to view the principles of work that must govern the surgery of such a war as this which has recently been waged. We cannot do better than to quote the paragraphs with which the author begins Chapter I.

"It is beyond the power of words to convey anything but the feeblest impression of the conditions under which surgical work is carried on at a very advanced unit during a big 'push.' For the doctor fresh from a palatial, well-ordered hospital, who has hitherto had all things made easy in virtue of his training and surroundings, and who may be so confident of obtaining good results that he dreams of performing marvelous operations at the front, there will be much to learn and much to unlearn. The dimly lighted dugout dressing-station, the dust, the wet, the mud, the blood, the noise, the bustle, the numbers of wounded, the appalling wounds, the hopeless shock, will open his eyes, test his capacity and resource, and tend to break his heart as never before. Here is no brilliantly lighted and fully equipped theatre, here his patients do not come before him in spotless apparel, here he has not unlimited skilled assistance, here no aseptic ritual is possible, here he must be content with very simple things. And through it all he must keep cool, he must hurry, he must be thorough, he must be gentle and careful in every possible way. His is the responsibility to make or mar a man for life. Often his patients shattered in nerve as well as in limb can give but feeble response to his utmost efforts so that a little slip in judgment, a little unnecessary exposure, a little lack of ordinary comfort even, or a little rough or unconsidered handling will tip the scale and send them to that death which their foes have desired.

"One is impressed by the fact that the methods of treatment which are most successful are those which are simplest and follow the indications of nature most closely. The medical officer who can land his patient at the next stage of the journey in best condition with the fewest contraptions serves his country best. Some measures described are so simple that, were they not so frequently neglected, it would appear almost superfluous to draw special attention to them. Principles of surgery remain the same, but the application of them is perforce adapted to local conditions. Original minds will always devise the means to the end in the greatly varying and new conditions which this war will continue to force upon them. At the field ambulance, at the casualty clearing station, at the hospital on the lines of communication in France, and at the base hospitals in England, the problems of surgery are widely different. Even the most skilful hospital surgeon of civil life must pass through an apprenticeship at any of these places before he becomes of the same value as his house surgeon of prewar days who has qualified in war surgery. The experience of even a few weeks may produce a wonderful revision of the standard of values.

"No work is done under such a variety of conditions as the work of

the field ambulance and of the regimental medical officer. The circumstances in which a field ambulance finds itself, and the resources at its disposal, are so different under the conditions of ordinary trench warfare and of a big engagement that it is impossible, as in the case of other units, to lay down hard and fast rules that are of more or less universal application. What is easily attained under ordinary conditions may be absolutely impossible during the heat of a battle, and methods of treatment that are well within the reach of ambulances working in one portion of the line, may be entirely impracticable to those working under less favorable conditions.

"The conditions of warfare demand that wounded men shall be got out of the way so that supplies of reinforcements, ammunition, and food to the fighting line are not interfered with. But while the primary function of advanced medical units is to clear the wounded as rapidly as possible, yet the enormous importance of preventive work must constantly be kept in mind. The effects of treatment of the wounded man at the earliest stages are reflected in the whole course of his subsequent illness. The influence of efficient early treatment cannot be overestimated. The fate of a life or limb is often determined before the arrival of the wounded man at the casualty clearing station, and no subsequent surgical skill can undo an error that has previously been committed. The 'results' of the casualty clearing station, to a great extent, reflect the good or the bad work of the forward units. Treatment begins when the patient is first seen, and not in the operating theatre. The prevention of early complications gives a man a good start in his struggle. Only the most necessary procedures can be carried out, but these must also be the best possible.

"*Shock.*—The intense surgical shock from which some of the wounded suffer must be seen in order to be appreciated. Primary shock from the injury is aggravated by unavoidable early handling and by transport of the patient. This fact is brought home in a negative way by the observation that a man with a fractured femur who lies out for a day or two after being wounded, arrives at the casualty clearing station in better condition on the whole as regards pure shock than one who is picked up and transported without delay. A comparatively smooth railway journey has a deleterious effect. How much worse is the effect of transport down uneven trenches, over rough country, and along bumpy roads! A wounded man left lying out keeps his limb at rest and recovers from the first shock of the injury. Close attention must be paid to these indications because other considerations compel the immediate removal of the patient to a place where he can be operated upon to the best advantage. Every effort must be made to prevent the summation of painful stimuli, which transport inevitably provides, from producing fresh shock or intensifying, beyond the patient's endurance, the shock already present. The most important elements in combating the development of profound secondary shock are rest, both mental and physical, and warmth. Rest during the journey is procured by proper fixation and efficient support of the injured part and prevention of jarring bumps. Com-

plete rest to the patient is out of the question at this stage and therefore the aid of sedatives has to be invoked, and should be used as early as possible in order to render him less sensitive.

"The great majority of the severely wounded give evidence of the existence of some degree of shock or collapse, and attention to their general condition is as important as attention to their wounds. Shock is generally due to the combined action of several causes, amongst which the most common are: (1) Hemorrhage; (2) exposure to cold, wet, hunger, and fatigue; (3) pain and anxiety; (4) the presence of multiple injuries; (5) the injury of some important organ, as in lesions of the trunk and head. Next to the actual injury, the journey from the trenches to the casualty clearing station is the most potent factor in producing shock, and every effort must be made to render his journey as easy as possible for the wounded man. This can only be done by attention to innumerable details, which, considered separately, may seem insignificant, but taken collectively may make the difference between life and death to the patient. Viewed in this light, no attention that contributes to the wounded man's comfort during his journey is so trifling as not to merit care and consideration. The good work of an ambulance rests on attention to these details rather than on the performance of surgical operations.

"There is no measure which is of such vital importance to a seriously wounded man as the provision of warmth. The first complaint heard in a regimental aid post is almost always of cold, and throughout the wearisome journey to the casualty clearing station the same complaint is repeatedly voiced. Many stretcher cases arrive at the clearing station so cold that the pain of their wounds has been relegated to the background, and in severely shocked cases the surface temperature may have sunk to as low as 90 degrees. During winter months the mortality from shock materially rises as the result of the increased cold.

"The chief protection of the wounded man against cold during the first part of his journey lies in the liberal use of blankets. At no time is the loss of heat more rapid than during the first two hours after wounding, and every effort must be made to prevent exposure to cold at this period. Nothing is more striking than the deterioration in condition that takes place when a stretcher case has been sent on his journey without a blanket beneath him as well as one on top.

"During bad weather wet clothing should be removed as early as possible and the wounded man put into a dry suit of pajamas. Sometimes this may be done at an advanced dressing station, but often no arrangements for the change into dry clothes are to be found further forward than the main dressing station. The advantages of an early change are enormous, and every effort must be made to accomplish it as far forward as possible. It is impossible to get a wounded man warm while he is surrounded by a cold compress of wet clothing, and to get a man warm is as important an item in ambulance treatment as to dress his wounds."

The subject of the application of dressings, the stanching of hemorrhage, the treatment of fractures, the special cares called for in head wounds, chest and abdominal cases, are all briefly considered.

A special chapter is devoted to the work at the casualty clearing station. The work of the casualty clearing station, he remarks, should be judged from the condition in which its patients arrive at the base rather than by the number of cases which it passes through, although in times of highest pressure the latter function becomes of equal, if not of paramount importance. On some occasions, indeed, the casualty clearing station has to be transformed into a glorified dressing station. Operations, unless most urgent and at the same time most hopeful, are given up for the time being. At all times the aim must be the greatest good to the greatest number. In conclusion of this branch of his subject he says that the surgeon fresh from civil practice will speedily find that war wounds in France behave very differently from those to which he is accustomed at home, unless they are treated efficiently on certain definite principles. If these principles are appreciated, common sense and good technic in their application will insure a great measure of success.

After a chapter devoted to the treatment of wound shock and to a general consideration of the use of antiseptic dressings, the author arrives at a consideration of the principles that should guide the treatment of gunshot wounds. Of chief importance is the principle that a patient who requires operation should be operated upon as soon as possible!

A long time elapsed before the value of free incision combined with excision of lacerated tissue was appreciated and before it was realized that gas gangrene must be treated on the same lines as sarcoma. Free incision relieves tension and thereby improves the local circulation. Excision removes parts which have had their circulation definitely obstructed and will become or already are affected with gas gangrene. The presence of anaërobic gas-forming organisms is so widespread in the soil of France that all lacerated wounds must be regarded as being infected by them. It is necessary, therefore, to excise all lacerated, or obviously infected, muscle until freely bleeding tissue is reached.

The difficulties which surround the operating surgeon of the casualty clearing station in many cases are extremely trying. If operation is performed too early, the patient will die of shock; if unduly postponed, he is likely to succumb from acute sepsis. It is difficult for those who have not had experience at the front to appreciate that infection can develop so quickly as it sometimes does. Men have succumbed to acute gas infection within twelve hours of the reception of the wound; in a large number it is well advanced in twenty-four to forty-eight hours. Acute septicæmia is frequently present at the same time, and, when due to streptococci, it is particularly fatal.

A full consideration is given to the early excision and suture of gunshot wounds, the method which became fully established as the method of choice in the last years of the war.

Wounds of the brain and its coverings are given full consideration in one of the most important chapters of the book.

The chapter which perhaps will arrest attention most certainly is the rather brief Chapter 8 devoted to the penetrating wounds of the thorax. Early in the war it became appreciated that the mortality of chest cases was high and that with very few exceptions only those of the more trivial types of wounds lived to reach base hospitals. In the case of open wounds, unless immediate operation was performed, it was quite exceptional for patients to get to the base at all. They died in an advanced hospital or en route.

It was long, however, before the general body of surgeons recognized that if great loss of life was to be avoided, such cases must be treated on the principles which govern patients with wounds in other parts of the body. The result of such active treatment has been that now the best operators send out over 70 per cent. of their cases of penetrating gunshot wounds of the chest recovered to such a degree that they gave every prospect of becoming useful citizens and some of them even able to return to full military duty again. As in wounds of other parts of the body, no case can be pronounced free from the danger of sepsis. The liability to early fulminating sepsis depends chiefly on the size of the wounds, especially of the entrance wound. Sepsis has been the cause of early death in most of the "sucking wounds" which reach the casualty clearing station. Between cases with closed chest wounds and those with open, possibly sucking wounds, there exist a fairly large number in which decision as to treatment is fraught with great difficulty and anxiety. The possibility of giving relief to the patient and preventing a problematical development of sepsis must be weighed against the danger which the operation necessary for such a double purpose involves.

The mortality from sepsis developing after the patient has been forwarded to a base hospital has been so great as to constitute a decided indication for interference in a larger number of cases at the casualty clearing station. There is, however, a large number of cases, constituting from 25 to 30 per cent. of the entire number, in which the nature of their wounds is such as manifestly to demand operation at the earliest possible moment. Mere closure of the wound will in no measure prevent development of sepsis, a condition which in this class of case is usually extremely virulent and lethal. Therefore, thorough excision of lacerated tissue and removal of blood clot and foreign bodies are essential to ultimate success in the treatment of penetrating wounds of the thorax, as in the treatment of gunshot wounds of other parts of the body. The lessening mortality which has followed the more frequent adoption of early radical operative means has been sufficient to furnish complete justification for such radical operation in severe cases.

A brief chapter follows devoted to injuries of the spinal cord.

Compound fractures of the femur are given a special chapter.

Wounds of joints are fully considered. One notes that in this chapter the author does not omit to make mention of the practice of Willems and other Belgian surgeons in instituting active movements of a wounded joint,

saying, that by their practice the hope has been aroused that even in suppurating joints, once the site of primary infection has been removed, a useful movable joint may be obtained. The theory on which their success is said to depend, that only by active movements can a joint be thoroughly drained, is so opposed to what surgeons have hitherto believed to be proper treatment that caution in adopting the method is excusable. But many old-fashioned notions have been upset during this war. One can remember well the incredulity with which the results of excision of wounds were received, and one cannot afford to neglect the brilliant results which have been demonstrated by the Belgians. It would appear necessary that if success is to attend such treatment, it must be initiated at a very early stage; it must not be instituted as a last resort, if it is to have a fair chance.

With this chapter upon wounds of the joints the book closes. It is good reading and may serve as an excellent epitome of the special elements of the Military Surgery of the recent war. It is free from wearisome statistics and is rather a discussion of principles with brief considerations of practical and technical details which at no time are permitted to be so numerous or minute as to embarrass the general progress of the more important plan of the work. We have quoted freely from many pages of this book, attracted by the importance of the considerations which it presents and, even more, by the attractive style and the literary value which these pages display.

LEWIS A. PILCHER.

CORRESPONDENCE

FREE TRANSPLANTATION OF TENDONS

EDITOR ANNALS OF SURGERY:

At the present time, when the surgical world is especially interested in problems of reconstruction, perhaps the details of an operation which was performed at the Samaritan Hospital three years ago would be of some interest, especially as it involved the use of a free tendon transplant. The literature of surgery is rather full of tendon transferrence and on the use of free transplantation of other tissues, but so far I have seen little mention of the use of tendons in the manner to be described.

A man fifty years of age presented himself at the orthopædic dispensary of the Samaritan Hospital with a disabled right hand, the result of a lacerating and crushing injury, followed by infection. The fourth and fifth fingers had been caught in a machine in a mill several months previous to the time that he presented himself to us. The resulting infection had necessitated the amputation of the fifth finger at the proximal joint. The flexor tendon of the stump had contracted to such a degree that the stump was in close apposition to the palm, and in that position was giving rise to great discomfort. The fourth finger had also contracted in a badly flexed posture, due to tendon contraction. It seemed that the joints of the fourth finger were unaffected, so far as we could determine clinically and by use of the X-ray.

It was therefore determined to amputate the stump of the fifth finger and to attempt a tenoplasty on the flexor tendons of the fourth. Under ether anæsthesia an incision was made on the palmar surface of the fourth finger from the distal joint to a point slightly below the metacarpo-phalangeal joint; the flexor sublimis was exposed and found to have been practically destroyed by the infection. The sheath of this tendon was also partially destroyed. The tendon and the sheath were freed and cut transversely, several other bands of adhesions being divided; the tendon of the flexor profundus was then exposed, and it was found to be in good condition; it was also divided transversely, as its size hardly permitted us to attempt the usual method of tendon lengthening. The finger could then be straightened, and it was found that the joints were freely movable; however, with the finger in the extended position there was a gap of an inch between the cut ends of the tendon. It was then decided to utilize the extensor tendon of the stump of the fifth finger for filling in this gap. Accordingly the tendon was exposed and a somewhat longer piece than was actually needed removed. The free transplant was then sutured in the gap of the flexor profundus, leaving a considerable overlap at either end. The sheath was closed with fine chromic gut, skin incision closed with no further regard to the flexor

sublimis tendon, the finger was dressed in full extension. The stump of the fifth finger was then amputated in the usual manner.

No infection occurred in the wounds. Passive motion was started at the end of sixteen days, he being treated three times weekly in the massage clinic. Gradually voluntary flexion control of the fourth finger developed, until at the end of two months he had about one-half normal flexion. Then he disappeared, and all efforts to locate him have been unavailing. There is little reason to doubt, however, that he gained a functionally useful finger.

While conclusions drawn from one case have little value, it would seem that in a hand where there are a number of disabled fingers and it is found necessary that one or more be sacrificed, that the tendons of the useless fingers, provided such tendons are in good condition, could be utilized in the manner described.

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COMPLETE TORSION OF GREAT OMENTUM

EDITOR, ANNALS OF SURGERY:

IN looking over recent literature, I have been unable to find a report of the whole great omentum twisted at the transverse colon without apparent cause, therefore I consider the following case a rarity and of sufficient interest to warrant its report.

Mr. Snyder was admitted to the Seton Hospital April 15, 1919, having been referred by Doctor Riecker of Cherry Grove, Ohio, with a tentative diagnosis of acute appendicitis. Examination revealed a robust man of thirty-seven years. He gave a history of having had three attacks of cramps during the past year, which were relieved in twelve to twenty-four hours by taking castor oil. During the last year he had suffered from so-called indigestion and made it a habit of taking some form of cathartic every night.

The present onset began about twenty-four hours before his entrance into the hospital, when he experienced a severe pain about his umbilicus. His temperature, taken at the hospital, was 98, his pulse 60 and respirations 18. Examination of his abdomen revealed no distention and no signs except a slight rigidity of his right rectus muscle and tenderness over his right lower abdomen.

Because he was complaining of pain and because of the rigidity and tenderness, with the history of his previous attacks, we thought it best to operate at once, even though his temperature and pulse were normal.

He was taken to the operating room and a right rectus incision made as in operating for appendicitis. When the peritoneum was reached it could be seen that there was blood underneath, giving the appearance which frequently presents itself in a ruptured ectopic in the female. Upon

opening the peritoneum dark blood immediately escaped from the peritoneal cavity and gangrenous omentum presented itself. The incision was immediately enlarged upward giving exposure of the entire abdominal cavity. It was then seen that the entire great omentum was gangrenous and twisted about five times at the transverse colon. The transverse colon was not twisted itself, but the omentum had torn itself loose from its splenic portion, thus accounting for the hemorrhage. The large and small bowel was apparently normal in every respect and the appendix was found normal. There was no hernia.

One point which struck me as significant was that the omentum had overlapped itself from left to right, that is, from the spleen towards the liver, so that its splenic attachment had been torn loose.

In trying to account for this condition I could find no basis other than his repeated catharsis, as he stated that he never missed a night without taking a physic. It seems far-fetched, indeed, to imagine that the antiperistaltic waves of the transverse colon could become increased to such an extent as to cause an overlapping of the great omentum, still this is the only explanation which I can offer. It is the only case which I have ever seen of this kind, and I have been unable to find any uncomplicated cases recorded in the literature. Hedley in the *Brit. Med. Journal* of November 11, 1911, studied records of 73 cases of torsion of the great omentum. In 60 cases there had been a hernia; in 5 cases there were adhesions without hernia. In a large portion of the cases the omentum was found in a sac.

My patient made a normal recovery after his omentum was removed.

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CINCINNATI, O.

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